Mechanical Engineering Technology

APRC 1997-1998

Section 1 of 4

MECHANICAL ENGINEERING TECHNOLOGY PROGRAM

ASSOCIATE DEGREE IN APPLIED SCIENCE

SELF STUDY FOR ACADEMIC PROGRAM REVIEW

Ferris State University
College of Technology

Big Rapids, Michigan 49307

September 22, 1997

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MECHANICAL ENGINEERING TECHNOLOGY PROGRAM
ASSOCIATE DEGREE IN APPLIED SCIENCE

College of Technology
Ferris State University
Big Rapids, Michigan 49307

September 22, 1997

PROGRAM REVIEW PANEL

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PREFACE

The Mechanical Engineering Technology (MET) AAS Program was selected for academic program review in the 1997-1998 cycle. This report, prepared by the Program Review Panel (PRP) and submitted to the Academic Program Review Council (APRC), responds to the requirements and guidelines established for the academic program review process.[1]

Organization of the report follows the Council guidelines. Section 1 presents an overview of the program, including mission, history, impact, expectations, and plans for improvement. Sections 2 through 9 cover results and analyses of the data collection activities. Section 10 reviews enrollment trends since semester conversion, and Section 11 presents program productivity and cost information. Section 12 contains conclusions based on the data analysis and Section 13 has recommendations addressing program strengths and weaknesses.

In 1996-1997 the MET program underwent review by a team from the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc. (TAC of ABET). As a result, the MET program has received accreditation by TAC of ABET.[2] The accreditation expiration date is September 30, 2003 and a request to ABET by January 31, 2002 is required for a reaccredidation visit. The documents (Attachments 1, 2, and 3)[3] prepared for this review contain a wealth of information concerning the program and are attached. For ease of reference, a topical index of subject matter contained in these reports has been prepared. Subjects covered in the present report also appear in this index. Graduates of the program, commencing May 1997 and thereafter, will receive TAC of ABET accredited AAS degree diplomas.

Also attached are the project written and oral presentations (Attachments 4 and 5)[4] from the most recent cycle of our capstone course, MECH 221, Mechanical Measurements with Computer Applications.

Taken together, this report and its attachments serve as a self-study handbook for the MET program. The expected regularity of ABET accreditation visits, APRC reviews and outcomes assessments means that these program self-studies have become regular fixtures in our academic landscape.

We wish to express our appreciation and thanks to our students, alumni, fellow faculty, staff, and industry representatives who contributed to this work.

The program review panel remains available to meet with the Council to discuss this report.

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[1] Appendix A: "Academic Program Review: A Guide for Participants." Office of Academic Affairs/ Academic Senate, Ferris State University, Big Rapids, Michigan 49307, June 1996.

[2] Appendix B: "TAC of ABET Notice of Accreditation." Technology Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc., Baltimore, Maryland, September 4, 1997.

[3]
1. *Self Study for Review of the Associate Degree Program in Mechanical Engineering Technology. Volume I -- The Institution.* Prepared for the TAC of ABET site visit. Ferris State University, College of Technology, September 3, 1996.
2. *Self Study for Review of the Associate Degree Program in Mechanical Engineering Technology. Volume II -- The Program.* Prepared for the TAC of ABET site visit. Ferris State University, College of Technology, September 3, 1996.
3. *Response to the TAC of ABET Preliminary Visitation Report.* Ferris State University, College of Technology, March 24, 1997.

[4]
4. *The 25th Anniversary Mechanical Engineering Technology Student Projects.* MECH 221, Mechanical Measurements with Computer Applications, May 1, 1997.
5. "Student Project Oral Presentations: Videotape." MECH 221, Mechanical Measurements with Computer Applications, May 1, 1997.

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ATTACHMENTS

1. *Self Study for Review of the Associate Degree Program in Mechanical Engineering Technology. Volume I -- The Institution.* Prepared for the TAC of ABET site visit. Ferris State University, College of Technology, September 3, 1996.

2. *Self Study for Review of the Associate Degree Program in Mechanical Engineering Technology. Volume II -- The Program.* Prepared for the TAC of ABET site visit. Ferris State University, College of Technology, September 3, 1996.

3. *Response to the TAC of ABET Preliminary Visitation Report.* Ferris State University, College of Technology, March 24, 1997.

4. *The 25th Anniversary Mechanical Engineering Technology Student Projects.* MECH 221 Mechanical Measurements with Computer Applications, May 1, 1997.

5. "Student Project Oral Presentations: Videotape." MECH 221, Mechanical Measurements with Computer Applications, May 1, 1997.

RESPONSE TO QUESTIONS ASKED BY THE ACADEMIC PROGRAM REVIEW COUNCIL

1. *How unique is your program? What other schools in Michigan offer it?*

A recent survey[1] of programs in engineering technology in Michigan came up with the following:

Engineering Technology AAS Degree Programs	Number	Community Colleges
[generic]	3	Delta North Central Michigan Oakland
Automotive	1	Monroe
Chemical	1	Alpena Kellog
Electrical & Electronic	5	Bay DeNoc Jackson Mott Lansing Wayne County
Environmental	3	Jackson Lansing Wayne County
Industrial	5	Alpena Montcalm Oakland Washtenaw Wayne County
Manufacturing	1	Henry Ford
Mechanical	3	Ferris State University Mid-Michigan Washtenaw

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[1] "Proposal for a Bachelor of Science Degree Program in Mechanical Engineering Technology," by the Faculty of the Department of Industrial Technology, College of Technology, Eastern Michigan University, November 27, 1996.

MECH 222 Machine Design
(4 lecture + 0 lab = 4 credits)
A faculty member from the product design program has been teaching this course. A similar course is offered to product design students.

4. *What is the effect of BS programs not requiring completion of AAS degrees?*

When transfer students from other schools are not required to have completed an AAS degree program, it becomes difficult to require such completion from Ferris students. We have responded to this problem by tracking down the miscreant non-degree completers. We strongly encourage them to complete their course work.

5. *What is the program capacity? What about the reduction in faculty from five to two?*

With present physical facilities and faculty resources, the program capacity is one section started each year. The number of students that may be accommodated in a section are about 36 (first year) and 32 (second year). More telling is the question of how the program can meet demand for its service courses. Starting Fall 1998, the new elastomer program will require offerings in fluid power and statics & strength of materials.

The reasons for changes in the number of program faculty include the following:

- Transfer of the metallurgy/material science lab and associated courses to the manufacturing program (c. 1987). The faculty member associated with this area was moved to the manufacturing program seniority group.

- One faculty member chose to take a coordinator position in the construction department (c. 1986).

- When Kimberly Gillett retired in 1992, the "restructuring" effort at Ferris was in full swing. To save an administrative position in the College of Technology, an act of "dodge ball accounting" was accomplished. Gillett's position was assigned to a new hire, William Winchell. Winchell had the title 'Associate Professor of Mechanical Engineering Technology,' but he was assigned to the manufacturing program. For a number of years his salary was billed to the MET program. This act has never been justified. It is essential that this position be restored to the MET program.

6. *Clarify the remarks concerning the possibility of a four year, BSMET curriculum initiative.*

An accredited BS program in mechanical engineering technology should be on offer to Ferris students. Such a program could be constructed primarily from present offerings. Mechanical engineering technology is a large house. It can accommodate offerings in design, experimental testing and manufacturing. It also would support and lead into the master's degree program in technology currently under consideration.

Also, combinations of programs could be put together: mechanical and electrical, mechanical and elastomer, mechanical and manufacturing, & etc.

7. *Has the admissions problem been solved?*

The ABET visitation team noticed that, on occasion, students were being admitted to the program who did not meet the requirement to start with MATH 116. Their ACT math score was below 19. This problem has been addressed to their satisfaction.[2] One problem that became known was the shortage, from time to time, of an adequate number of sections of remedial math and English courses (MATH 010, MATH 110, and ENGL 074). It was estimated that the teaching shortage in this area amounts to about three full time equivalent faculty.

8. *What is your response to the employer survey comment regarding the new elastometer program?*

Curriculum developments in the MET area have been moribund for a number of years. "Restructuring" has had a serious impact in this area. With the completion of two major self-evaluation efforts over the last two years (TAC of ABET accreditation and academic program review), serious attention should be given to curriculum initiatives. The elastomer science area would offer a natural opportunity for creative curriculum development.

9. *What are your concerns concerning the section shortages for ENGL 074, MATH 010 and MATH 110?*

As noted in item 7 above, there all too often are insufficient sections of remedial courses to accommodate the pre-technical students admitted to our programs. The responsibility for these offering lies with the College of Arts and Sciences.

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[2] See Appendix B, "Final Visitation Report on Ferris State University," Technology Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc., Baltimore, Maryland, page B-11.

10. *What are your recruitment and publicity strategies?*

Because of the shortage of program faculty and because of the recent preoccupation with program self-studies, little has been done in these areas. The program has relied on the reputation it has acquired over the last quarter of a century.

11. *What are the profiles of MET students?*

Profiles of the current crop of MET students are presented on pages 4-2 and 4-3 of our report. Just this week the high school grade point averages and ACT score profiles of students entering the DMGA department have been released. The averages for entering MET students are as follows.

High School GPA	**Percent MET 1st Year Students**
3.75 to 4.00	0
3.50 to 3.74	11
3.25 to 3.49	26
3.00 to 3.24	11
2.75 to 2.99	5
2.50 to 2.74	32
2.25 to 2.49	5
2.00 to 2.24	5
1.75 to 1.99	5

ACT Score Category	**Average Score for MET 1st Year Students**	**Average Score for DMGA Department**
Composite	21.2	19.5
English	18.7	17.7
Math	22.9	20.1
Reading	19.6	19.0
Science Reasoning	22.8	20.8

Because of the number of transfer students and foreign students in the MET program, these numbers describe only 19 out of 30 first year students.

12. *Why do you propose to add more lab time to the program?*

We plan to submit a curriculum proposal with the following elements:

- Change MECH 111 MET Seminar (1 lecture + 0 lab = 1 credit) to (0 lecture + 2 lab = 1 credit). This course is offered each Fall semester for first year MET students. This change would allow more concentration on project activity.
- Add MECH 1xx MET Laboratory 1 (0 lecture + 2 lab = 1 credit). This course would be offered each Winter semester for first year MET students. This course would complement student work in applied mathematics (MATH 126) and applied physics (PHYS 211). It would also introduce the students to the MET laboratories. Laboratory procedures and protocol would receive special attention.
- Add MECH 2yy MET Laboratory 2 (0 lecture + 2 lab = 1 credit). This course would be offered each Fall semester for second year MET students. This course would complement student work in applied calculus (MATH 216) applied physics (PHYS 212), and statics and strength of materials (MECH 240).

In semester conversion there was a great reduction in lab hours for MET courses, as shown below.

Course	**Total Lab Hours**	
	Before Semester Conversion	**After Semester Conversion**
Drafting & CAD	120	45
Statics & Strength of Materials	40	0
Fluid Mechanics	80	45
Kinematics	30	0
Machine Design	60	0
Mechanical Measurements	60	45

It should be noted that a number of these labs involved problem solving using drafting methods (kinematics and strength of materials for example) that are now replaced by use of calculators and computers. But the net effect has been to leave the Met labs somewhat underutilized.

13. *What has been the impact of curriculum changes over the years?*

Since its inception, the MET curriculum has remained relatively stable. The most significant change has been the move away from the drafting table and into the computer lab, as noted in item 12 above. An applied calculus course was added in 1983 and then temporarily removed in the years from 1993 to 1996. Otherwise, the program has maintained its focus on the essential elements in mechanical engineering technology. This curriculum is summarized on pages 1-1 to 1-3 of the report.

SECTION 1

OVERVIEW

A. GOALS AND OBJECTIVES OF THE MET PROGRAM

The associate in applied science degree program in mechanical engineering technology (MET) originated in Fall quarter, 1970. It was the first engineering technology program at Ferris. Its goals and objectives have been stated as[1]

1. Educational Goals.

At Ferris the MET students learn to make graphic drawings; apply mathematical and physical principles to the solution of technological problems; design mechanical components and machines; perform engineering tests for such quantities as stress, strain, torque and temperature; apply principles of fluid mechanics, fluid power and thermodynamics; specify material selection and processing; collect test data; and prepare technical reports. Students acquire written and verbal skills through the study of English, humanities and behavioral sciences courses.

2. Occupational Skill Levels of MET Graduates.

A MET graduate can assist in developing and testing new machinery and equipment, review product instructions and drawings for specifications, operate test equipment, gather test data and prepare engineering charts and graphs.

3. Service to the Community, State and Nation.

The MET program provides service to the larger community by adding to the pool of trained technicians and designers that can meet the present and future challenges of advancing technologies.

Allowing for ever-changing technology, the program still aspires to accept the challenges stated in these goals and objectives. These program objectives also support the mission of the University.

> Ferris State University will be a national leader in providing opportunities for innovative teaching and learning in career-oriented, technological and professional education.

It is our duty in this report to show how these objectives are being accomplished.

B. HISTORY OF THE MET PROGRAM

The MET program was launched Fall quarter, 1970; the first graduates completed their studies in May 1972. This was the first engineering technology program at Ferris. At that time the majority of the programs in technology ran four quarters and granted certificates. These included areas such as welding, machine tool, drafting, auto body, auto paint and auto service.

In 1977, a BS program in manufacturing engineering technology was initiated. Now MET AAS graduates could ladder into a four-year degree program. Quite a few of them did. Today, alumni (AAS MET and BS MfgET) from the late 1970's and early 1980's have achieved success in the manufacturing industry. Many have "manager" in their job title.

In 1988, a BS program in product design engineering technology was added. This program annually enlists a goodly number of our graduates. Although it is too early to see long-term career development, some of the alumni who pursued the AAS MET plus BS PDET path are starting to make their mark.

C. CURRICULUM DEVELOPMENT

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[1] Attachment 2, Appendix H, page H-1.

A review of the history of the MET AAS curriculum and how it has evolved reveals that there has been little change in the core curriculum. The original core program courses, offered in the second year of study, are still represented by the current list[2]:

MECH 211 Fluid Mechanics	(3 lecture + 3 lab = 4 credits)
MECH 212 Kinematics of Mechanisms	(2 lecture + 0 lab = 2 credits)
MECH 221 Mechanical Measurements with Computer Applications	(3 lecture + 3 lab = 4 credits)
MECH 222 Machine Design	(4 lecture + 0 lab = 4 credits)
MECH 223 Thermodynamics and Heat Transfer	(3 lecture + 0 lab = 3 credits)

An important support course is EEET 215, Electricity and Electronics for MET (3 lecture + 3 lab = 4 credits). Its electrical applications are used in our capstone mechanical measurements course, MECH 221.

Our program has a concentration of applied mathematics and science courses, including

MATH 116 Intermediate Algebra and Numerical Trigonometry	(4 lecture + 0 lab = 4 credits)
MATH 126 Algebra and Analytic Trigonometry	(4 lecture + 0 lab = 4 credits)
MATH 216 Applied Calculus	(4 lecture + 0 lab = 4 credits)
PHYS 211 Introductory Physics 1	(3 lecture + 3 lab = 4 credits)
PHYS 212 Introductory Physics 2	(3 lecture + 3 lab = 4 credits)

Related introductory first year courses include:

ETEC 140 Engineering Graphics Comprehensive	(2 lecture + 3 lab = 3 credits)
MFGT 150 Manufacturing Processes	(1 lecture + 3 lab = 2 credits)
MECH 122 Computer Applications in Technology	(2 lecture + 0 lab = 2 credits)

MET students in two years spend 315 hours in various laboratory settings. This "hands-on" approach has been a Ferris hallmark.

The program includes the required distributions of English (6 credits) and other general courses education (6 credits).

The technical mathematics sequence was first developed within the program in 1983. At that time, the mathematics department did not offer technical math. For accreditation reasons, it was necessary to adopt math-prefix courses. This was accomplished in 1988 when the present technical math sequence was initiated.

D. TAC OF ABET ACCREDITATION

Interest in program accreditation first surfaced in 1983. A consultant was brought in to review accreditation possibilities for the manufacturing engineering technology BS program and its feeders, the MET, technical drafting and tool design, and machine tool technology programs. The MET program curriculum was realigned to meet criteria[3] established by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc. (TAC of ABET). The professional organization that develops the ABET criteria for mechanical-related curriculums is the American Society of Mechanical Engineers (ASME). ABET is the logical accreditation agency for MET. However, no accreditation action was taken at that time and the issue lay dormant until recently.

In the early 1990's, MET students began to inquire about our accreditation status. They lobbied to achieve

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[2] The current MET program curriculum guide sheet is in Attachment 2, Appendix A. Course outlines appear in Attachment 2, Section 11.

[3] The TAC of ABET criteria appear in Appendix C.

suitable accreditation. Our Industry Advisory Board also gave support to an accreditation effort. In January 1996, the University made formal application for an ABET accreditation site visit.

Meanwhile, a curriculum proposal[4] was submitted. Its purpose was to realign the MET curriculum with the TAC of ABET criteria. There was a credit-hour squeeze associated with semester conversion. The full-fee credit hours were limited to a maximum of 16 per term and the general education requirements were increased by two semester credit hours. To achieve the new lower credit-hour target, the applied calculus course was dropped. That course, and a second physics course, had to be put back into the program.

The curriculum proposal was approved and adopted and the ABET evaluation activities[5] were carried to a satisfactory conclusion.

The preliminary TAC of ABET visitation report is reproduced in Attachment 3, Appendix A, while the final visitation report appears in Appendix B of the present document. The MET program accreditation expires September 30, 2003. The deadline for a re-accreditation application is January 31, 2002.

Bringing the MET program under the TAC of ABET umbrella has numerous benefits. It ensures transferability of students' credits to other institutions, it generates favorable publicity for the program and for Ferris, and it supports the University in its accreditation dealings with the North Central Association of Colleges and Universities (NCA).

E. MET PROGRAM FACULTY

Resumes for current program faculty appear in Attachment 2, Section 2, pages 2d-2m. Recent faculty development, consulting and community service activities for Professors Drake and Olsson are detailed in Appendix F and in Attachment 3, Appendices H and I.

There have been only four tenured faculty associated with the MET program since its inception:

Kimberly Gillett, BSME, MSME, PE, Professor Emeritus	(1969-1993)
Hiram Herrick, BS, MS, PE, Professor Emeritus	(1978-1992)
George Olsson[6], BS, MS, PhD, Professor	(1979-1998)
Charles Drake[7], BS, MSME, PE, Associate Professor	(1990-)

The continuity shown here has been an important factor in program success. Several other faculty, now associated with other programs, originally were hired in connection with the MET program:

David Anderson	(manufacturing engineering technology program)
Mark Hill	(technical drafting and tool design program)
Charles Matrosic	(assistant dean and department head, construction and facilities)

There currently is a temporary full time appointee, Rick Haut, whose time is divided between the MET and the manufacturing programs.

The Board of Trustees has approved the tenure track MET position replacing Professor Olsson for January 1998. An application will be made to replace the temporary full time position with a tenure track position, effective Fall 1998.

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[4] See Attachment 2, Appendix B.

[5] See Appendix D, "Schedule of Events for TAC of ABET Accreditation Process - MET Program." This calendar of events was derived from the TAC of ABET document contained in Appendix E.

[6] The Board of Trustees has approved Professor Olsson's retirement, with Emeritus status, effective January 16, 1998.

[7] Last Spring Charles Drake was granted tenure (he was temporary full time 1990-1992) and received promotion to Associate Professor rank.

Securing qualified replacement faculty is a major challenge. In the "restructuring" process that occurred a few years ago, the replacement for Professor Gillett was assigned to the manufacturing engineering technology program, even though he was listed as "associate professor of mechanical engineering technology." For several years, that faculty member's salary and benefits were billed to the MET accounts. This has distorted MET program cost and productivity calculations.

To cover the discrepancy between MET teaching loads and the availability of program faculty, others have been called in to fill the gap. Current examples of faculty borrowed to teach our courses include the following:

Richard Goosen, PDET program	
MECH 222 (4 credits)	Winter 1997 and Winter 1998
MECH 240 (4 credits)	Fall 1997
Rick Haut, temporary full-time	
MECH 240 (4 credits × 2 sections)	Winter 1997 (probable for Winter 1998)
MECH 250[8] (5 credits total)	Winter 1997 (probable for Winter 1998)
James Rumpf, MfgET program	
MECH 122 (2 credits)	Winter 1997 and Winter 1998
Dan Wanink, temporary part-time	
CADD 490[9] (3 credits × 2 sections)	Winter 1997 (probable for Winter 1998)

The number of MET program faculty should be restored to three.

F. STUDENTS

Our students are a diverse group. Among our first-year group, there is a student from Kenya and a student from Saudi Arabia. Ten percent are female. Several are older, non-traditional, students. Several more are African-American. In the past, these groups have not been well represented in technology programs. Geographically, we have out-of-state students from Illinois and Wisconsin. This diversity enhances our students' educational experience.

Many of them are related to Ferris graduates. In effect, there is in place a word-of-mouth recruiting network for our program. Of the two chosen as outstanding second year students last spring, one is the daughter of a Ferris graduate and the other is the son of parents currently attending Ferris.

Admission criteria for students entering the MET AAS program are described in Attachment 3, Appendix B, pages B-1 to B-12. Regular admission requires an ACT math score of 19+. Candidates with lower scores may be admitted with pre-technical status (PMEC).

In recent years, some problems have arisen with the admissions process. This has received administrative attention (see memo from Dean Curtis on this subject, Attachment 3, Appendix B, page B-13). The admissions data for students entering the MET program, 1994-1996, are tabulated in Attachment 3, Appendix C. Another problem has been the shortage of remedial math and English courses (MATH 010, MATH 110 and ENGL 074) for entering pre-technical students.

About 80% of the students completing the program continue their education. This has been true for more than a decade. This gives the program an added role, preparation for academic success at the baccalaureate degree level.

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[8] MECH 250, Fluid Power with Controls, is a support course primarily for plastics students. It has a one-hour combined lecture plus four lab sections, two hours each.

[9] CADD 490, Special Studies in FEA and Mold flow, is a support course primarily for plastics students, usually taught by Professor Drake.

For many years, there was no organization of MET students. In the early 1990's new leadership appeared. The Mechanical Engineering Technology Association (META) was formed and it has provided a focus for student activities.

G. ALUMNI

Approximately 280 Ferris graduates have received an AAS degree in mechanical engineering technology. Others have completed our capstone course in mechanical measurements but have not fulfilled all of the requirements. Efforts are being made through telephone-data-base searches to locate those with unknown addresses.

Professor Gillett, who taught the capstone course for twenty years, left behind his grade books. These rosters were compared with official alumni lists and with College of Technology graduation records. We found 46 AAS MET graduates not on the alumni list.

As an outgrowth of the present self-study, an up-to-date alumni directory is in preparation.

With our alumni, we will be celebrating the twenty-fifth anniversary of the first class of MET AAS graduates in 1972. The event, scheduled for Ferris Homecoming on Saturday, October 18, 1997, will be a luncheon held at the Ferris Conference Center.

H. FUND RAISING

The University does not budget for capital equipment. Neither does it fund equipment repair and replacement. In the College of Technology, equipment is obtained through donations from industry and money received from the Vocational-Educational State and Federal financed program. The latter is intended for two-year programs and remains the chief source of support for the MET labs.

Acquiring adequate funds to support our MET laboratories remains an on-going challenge. We have in the planning stages two fund raising initiatives. These efforts are being coordinated with the Financial Affairs and Alumni offices.

- Alumni Endowment Fund

  Before the end of the year, alumni will be asked to pledge $400 to the MET program. (A married couple would receive in compensation a $200 State of Michigan tax credit; the corresponding tax deduction on Schedule A would be worth about another $100 on their Federal tax return. Net cost to them would be less than $100.)

  Some employers, such as the Ford Motor Company, match their employees' donations. In such cases, the $100 net cost translates into $800 received by the program.

  The proceeds of annual alumni donations to the program will be accumulated in an endowment fund. Revenues from the fund will be dedicated to student scholarships, faculty development and laboratory equipment and supplies.

- Capital Equipment Fund Raising Initiative

  The approach taken here is to establish a leadership committee from industry. The committee members will lend their names to the solicitation of major gifts. Companies will be given opportunities to equip and name entire laboratories.

G. SERVICE

The MET program provides service to the University, to the community and to the State and nation through its students, its faculty and its alumni.

Services provided by the faculty are detailed in resumes contained in Attachment 2, Section 2, pages 2c-2m. More recent activities are noted in Appendix F and in Attachment 3, Appendices H and I.

A number of services are provided by our students through META. Efforts of particular note include:

- Participation in the Michigan Department of Transportation (MDOT) Adopt-a-Highway program. The signs designating the two-mile stretch of US 131 roadway assigned to META appear at the 122 and 124-mile markers.
- Helping organize and run the Annual College of Technology Student Technical Symposium. MET students solicit companies to attend the symposium and make presentations. They also prepare exhibits and demonstrations of student accomplishments.
- Aiding special programs of instruction for middle and high school students.
- Organizing and fielding intramural sports teams.

SECTION 2

GRADUATE SURVEY

A. INTRODUCTION

<u>Graduate follow-up survey:</u> *The purpose of this activity is to learn from the graduates their perceptions and experiences regarding employment based on program outcomes. The goal is to assess the effectiveness of the program in terms of job placement and preparedness of the graduate for the marketplace. A mailed questionnaire is most preferred; however, under certain conditions telephone or personal interviews can be used to gather the data.*

An MET alumni survey was conducted as part of the TAC of ABET accreditation process. The cover letter and forms used appear in Appendix G. To maximize response, the survey instrument was intentionally made brief. This was a success. The initial response rate for the first mailing 210 questionnaires was about 37%. This contrasts with the response rate for College of Technology alumni surveys conducted by personnel at the Technology Transfer Center (TTC)[1]. The TTC survey return rates most often have been less than 10%. (Note that their survey instruments run to 10 pages).

B. MET ALUMNI DATA BASE

It was concluded that many of the alumni addresses were no longer valid. The Annual Giving/Development Services office was contacted. They ran an address data base analysis for us. Many corrections were found and follow-up mailings were made. Through word of mouth, we located alumni working abroad on assignments in Brazil and in England.

It was noticed that the alumni list obtained from Development Services was incomplete. Professor Gillett left behind all his grade books. Class lists from the capstone mechanical measurements course, which Gillett taught from 1972 through 1992, were compared with College of Technology graduation records and with the alumni lists. We found 46 alumni who received AAS MET degrees but who were missing from the MET alumni lists. A search for their addresses is under way.

A tabulation of the number of students completing the capstone course (light gray bar) and receiving their AAS MET degree (dark gray bar) is graphed in Figure 2-1. Several of these students (from as far back as 1990) are still attending Ferris. Typically, they lack an English class or a general education elective.

C. SURVEY QUESTIONS

The survey questions covered the following subjects:

Company, company address, telephone and e-mail address
Home address and telephone
Title
Salary range
Additional degrees
Recent seminars and courses
Career avenue
Ranking of relevant scientific and technical topics (corresponding to MET course of study)

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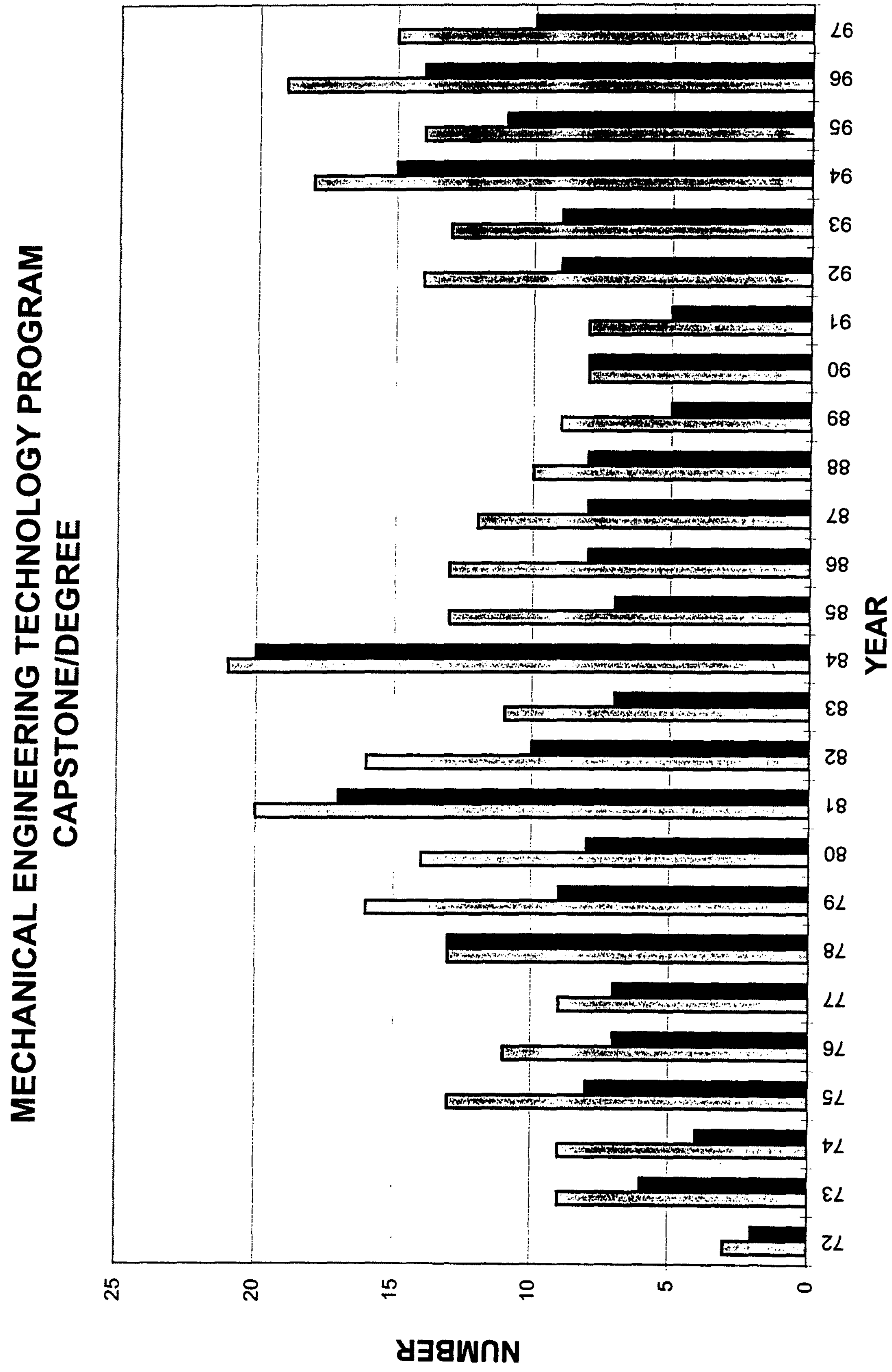
[1] College of Technology Alumni Survey 1995, questionnaire supplement, page 115.

FIGURE 2-1


MECHANICAL ENGINEERING TECHNOLOGY PROGRAM
CAPSTONE/DEGREE
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10
15
20
25
YEAR
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D. ALUMNI JOB TITLES

Table 2-1 lists MET alumni job titles. The most frequently mentioned include the designation *engineer* (42%) or *manager* (29%). The oldest of the alumni were about 20 in 1972 and now are 45. Thus, many of them are approaching their peak earning power and advancement. The results of an alumni telephone survey conducted in 1987 did not show the same degree of success.

TABLE 2-1

MECHANICAL ENGINEERING TECHNOLOGY ALUMNI SURVEY – 1996
JOB TITLES

Title		Number	Total	Percent
Chief Engineer		1	1	1.3
Coordinator		1	1	1.3
Designer		3	3	3.9
Director	Management Division	1	2	2.6
	Production	1		
Engineer		1	35	45.5
	Account	1		
	Applications	1		
	Customer	1		
	Design	3		
	Development	1		
	Fasteners	1		
	Installation	1		
	Manufacturing	7		
	Mechanical	1		
	Plant Vehicle	1		
	Product	5		
	Program	1		
	Project	4		
	Quality	1		
	Sales	1		
	Test	1		
	Tooling	2		
	Works	1		
Graduate Assistant		1	1	1.3
Human Resources	Consultant	1	1	1.3

TABLE 2-1 (CONTINUED)
MECHANICAL ENGINEERING TECHNOLOGY ALUMNI SURVEY - 1996
JOB TITLES

Title		Number	Total	Percent
Manager	Claims Systems	1	18	23.4
	Engineering	6		
	Plant	3		
	Project	2		
	Quality	3		
	Sales	3		
President and CEO		1	1	1.3
Proprietor		1	1	1.3
Publications	Group Leader	1	1	1.3
Sales Coordinator		1	1	1.3
Superintendent	Construction	1	1	1.3
Supervisor		1	3	3.9
	Engineering	1		
	Mold Department	1		
Teacher		1	1	1.3
Technician	Senior	1	4	5.2
	Instrument Maker	1		
	Mechanic	1		
	Substation	1		
Vice President		2	2	2.6
Total			**77**	**100%**

These titles can be regrouped in four categories:

Company Officer/Manager/Chief/Director/Supervisor	29	**38 %**
Engineer	35	**46**
Technician	4	**5**
Other	9	**12**
	77	
		00 %

It can be seen that a plurality of engineering technology alumni end up with engineering titles. Many of the duties assigned to engineering graduates can be performed by engineering technologists. Typically, as shown here, the engineering technologist works closer to the shop floor. Typical assignments are as manufacturing engineers, project engineers and plant managers.

E. SALARY RANGES

The salary compensation covers a wide spectrum, given the range of job titles from *president* to *graduate assistant.* The percentage distributions for the respondents are shown in Table 2-2.

The progression of salaries with time is evident. Ask not what starting salaries are. Ask what is achieved in terms of income and responsibility 10 to 15 years down the road.

TABLE 2-2
SALARY RANGES: PERCENTAGE OF RESPONDENTS

Salary Range	All	72 - 89 Graduates	90 – 94 Graduates
> $ 50 000	44	60	5
$ 46 – 50 000	14	15	11
$ 41 - 45 000	6	4	11
$ 36 – 40 000	15	11	26
$ 30 – 35 000	15	6	37
< $ 30 000	6	4	11

F. ADDITIONAL DEGREES

The majority of the alumni continued their education past the associate degree. A few have obtained master's degrees. The breakdown by percentage of respondents is as follows:

AAS Degree Only	32 %
BS Degree in Progress	4
BS Degree	68
MS Degree	4

Until the 1980's, the AAS degree was a satisfactory terminal degree. It remains a useful stepping-stone to higher education and to technical career.

G. RANKING OF ACADEMIC SUBJECTS

A list of technical and scientific topics, mostly corresponding to MET program course work, were presented. The respondents were asked to rank the subjects according to the importance they had in the respondent's career. The rating scale was simple:

1 = Very Important
2 = Necessary
3 = Unimportant.

The compiled ranking of subjects is presented in Table 2-3. If there is a surprise, it might be the high ranking of mathematics. Because of the pervasive intrusion of statistics into every professional discipline, there is a growing need for technologists to have increased mathematical understanding. While short courses of great variety are available for applied technical subjects, one learns math only in school. This is a justification for the restoration of a semester of applied calculus to the MET program.

None of the subjects was deemed unimportant. This is an indication of the broad scope of knowledge necessary for the practice of engineering technology in the mechanical, manufacturing and product design areas.

Computer applications deserve special attention. The College of Technology is continuing its investment in computing resources. The MET program is steadily adding and integrating computer applications in its course work.

TABLE 2-3
RANKING OF ACADEMIC SUBJECTS

Rank	Subject	Average Score
1	Manufacturing processes	1.45
2	Mathematics	1.46
3	Drafting	1.56
4	Mechanical measurements	1.63
5	Machine design	1.64
6	CAD	1.69
7	Statics & strength of materials	1.70
8	Electronic spreadsheets	1.71
9	Computer application software	1.73
10	Fluid power	1.79
11	Electricity & electronics	1.83
12	Physics	1.89
13	Fluid mechanics	1.89
14	Material science/metallurgy	1.90
15	Computer programming	2.09
16	Kinematics of mechanisms	2.14
17	Thermodynamics & heat transfer	2.21

SECTION 3

EMPLOYER SURVEY

A. INTRODUCTION

This activity is intended to aid in assessing the employers' experiences with graduates and their perceptions of the program itself. A mailed instrument should be used to conduct the survey; however, if justified, telephone or personal interviews may suffice.

The employer, or industry, survey was conducted by telephone. Through our network of alumni and industry advisory board (IAB) members, we obtained referrals to people who have oversight on technical employment. The survey form and a list of participating companies are presented in Appendix H.

The questions were short and to the point:

1. How many Ferris graduates do you employ?
2. What percentage have the skills you require?
3. What improvements are needed in the preparation (undergraduate education) of that group?
4. Would you consider hiring a Ferris graduate again in the future?

With these questions, the data were gathered in short, frank interviews.

B. DISTRIBUTION OF FERRIS GRADUATES EMPLOYED

The companies were screened for those that employed Ferris MET AAS graduates . The distribution of the number of such graduates was as follows.

1 - 5 graduates	13 respondents	87 %
6 -10	1	7
11 - 15	1	7

The company employing the largest number of MET alumni is the Prince Corporation.

C. PERCENTAGE THAT HAVE THE NECESSARY SKILLS

Two-thirds of the companies rated Ferris graduates as having 100 % of the necessary skills. The average skill rating was 94 %.

100 % skill rating	10 respondents	67 %
90	1	7
80	1	7
75	1	7
60 - 74	1	7
Prefers co-op students	1	7

D. NEEDED IMPROVEMENTS IN UNDERGRADUATE EDUCATION

The responses reflect individual circumstances at the various companies. A company that specializes in rubber applications (engine mounts, supports for vibrating machinery, & etc.) called for the joining of the MET program with the new Rubber Technology program[1] at Ferris. A company that produces and markets CAD-CAM software looks for more preparation in that area.

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[1] A new building, representing a major addition to the College of Technology and dedicated to rubber technology, presently is under construction. Soon, a new course of study in rubber technology will be in place.

In the Alumni Survey (see Section 2 above), 38 % of the respondents had managerial titles. This is reflected in a call for more business courses.

The compiled comments were:

Satisfied or no comment:	7	47 %
Institute internships	2	13
More hands-on, more lab work	2	13
More CAD-CAM training	1	7
Add business courses for technology students	1	7
Follow on the MET program with Rubber Technology	1	7

The results of this survey have suggested to us the following actions. They presently are under consideration.

- Add two semester of a one-credit MET lab, two hours per week
- Help MET students find summer jobs on a systematic basis
- Improve laddering arrangements for MET graduates into the Plastics and Rubber Technology programs
- Re-examine the first-year drawing and CAD course work for MET students.

E. WOULD A COMPANY HIRE A FERRIS GRADUATE IN THE FUTURE

This is the payoff question: given the opportunity to hire a Ferris graduate again, at some future time, would they do it? There were no hesitations in the expressions of willingness to continue to look to Ferris graduates as potentially useful and productive employees. *One hundred percent* responded in the affirmative.

SECTION 4

STUDENT EVALUATIONS

A. INTRODUCTION

Student evaluation of instruction: Students are surveyed to obtain information regarding quality of instruction, relevance of courses, satisfaction with program outcomes based on their own expectations. The survey must seek student suggestions on ways to improve the effectiveness of the program and to enhance the fulfillment of their expectations.

Three sets of student surveys were obtained:

(1) MET program enrollees entering Fall 1997,
(2) MET students starting their second year in Fall 1997,
(3) MET students completing their second year (and their MET AAS degree) in May 1997.

The survey instruments appear in Appendix I. The surveys were timed to catch the students at three points in the program: the start, the middle, and the finish.

B. SURVEY RESULTS FOR FIRST YEAR MET STUDENTS

The newly enrolled first year MET students were surveyed in August 1997. The quantitative data obtained from them is displayed in Table 4-1, parts (a) through (g).

TABLE 4-1
SURVEY DATA FOR ENTERING FIRST YEAR MET STUDENTS

(a) Year of graduation from high school

Year	Number	Percent
97	17	71
96	2	8
95	1	4
93	1	4
92	1	4
89	1	4
77	1	4

(b) Number of transfer students

Transfer	Number	Percent
Yes	5	20
No	20	80

(c) Gender

	Number	Percent
Male	27	90
Female	3	10

(d) Who helped decide on Ferris?

Who helped guide the student to Ferris (Mark all that apply)	Number
Friends	13
Parents	12
Other relatives	6
Counselor	5
Teacher	5
Co-worker	4
Self	3
Ads	2
Coach	1
Financial aid	1
Internet	1

(e) Who helped decide on entering the MET program

Who helped guide the student to Ferris (Mark all that apply)	Number
Parents	11
Self	10
Friends	7
Teacher	7
Counselor	6
Co-worker	5
Other relatives	2

(f) View on admissions processes

View	Number
Very favorable	2
Favorable	18
Neutral	8
Unfavorable	0
Very unfavorable	0

(g) What next after MET

Plan		Total	Percent
Go to work		2	8
Work & part-time school		2	8
Ferris BS		20	83
PDET	8		
MfgET	9		
Plastics	1		
Other	2		
Another university		1	4
Don't know		1	4

We see that 20 % are transfer students and 29 % completed high school before 1997. This freshman class exhibits considerable diversity. Ten percent are female, ten percent are African-American, one is from Kenya and one is from Saudi Arabia. They come from 25 different high schools, one in Illinois and one in Wisconsin. This diversity enhances each student's opportunity for a quality educational experience.

The admissions process (application, admission, financial aid, orientation and registration) fared well. Over 70 % have a favorable attitude.

It can be seen that parents and friends have the strongest influence on college choice decision making. This is true both for choice of university and choice of program.

Most students hope to continue their education after receiving their MET AAS degree. 83% plan to complete their studies at Ferris. This bodes well for the University.

They have received a very favorable impression of the College of Technology, the MET program and the faculty.

C. SURVEY RESULTS FOR SECOND YEAR MET STUDENTS

The quantitative data for the second-year students, surveyed in September 1997, are displayed in Table 4-2, parts (a) to (g). Of 22 new second-year students, 19 completed the questionnaire. There are similarities with the first-year class and there are differences. 63 % of the second-year students are transfer students. Almost a third completed high school by 1993. Over half have a neutral or unfavorable view of the admissions or financial aid process.

TABLE 4-2
SURVEY DATA FOR SECOND YEAR MET STUDENTS

(a) Year of graduation from high school

Year	Number	Percent
96	6	30
95	6	30
94	1	5
92	3	15
91	1	5
87	1	5
80	1	5

(b) Number of transfer students

Transfer	Number	Percent
Yes	12	63
No	7	37

(c) Gender

	Number	Percent
Male	18	95
Female	1	5

(d) Who helped decide on Ferris?

Who helped guide the student to Ferris (Mark all that apply)	Number
Self	9
Counselor	4
Parents	3
Friends	2
Other relatives	2
Teacher	1
Want ads	1

(e) Who helped decide on entering the MET program

Who helped guide the student to Ferris (Mark all that apply)	Number
Parents	11
Self	10
Friends	7
Teacher	7
Counselor	6
Co-worker	5
Other relatives	2

(f) View on admissions processes

View	Number
Very favorable	3
Favorable	5
Neutral	9
Unfavorable	1
Very unfavorable	0

(g) What next after MET AAS

Plan		Total	Percent
Go to work		1	7
Work & part-time school		0	0
Ferris BS		11	73
PDET	6		
MfgET	4		
Plastics	0		
Other	1		
Another university		2	13
Don't know		1	7

(h) Views on Faculty, Equipment and course of study

Attitude	View on MET Faculty	View on 1st Year Labs	View on MET Program
Very favorable	5	2	3
Favorable	14	10	13
Neutral	0	3	3
Unfavorable	0	3	0
Very Unfavorable	0	0	0

A similar percentage of first and second year students intend to stay on at Ferris (83 % and 79 %, respectively). The primary destination points for both groups are the product design and the manufacturing engineering technology BS programs.

D. SURVEY RESULTS FOR SECOND YEAR STUDENTS COMPLETING THE PROGRAM

The second-year students completing the program in May 1997 were asked the following questions. (The survey form appears in Appendix I.)

Employment plans?
Further education plans?
Why did you enter the MET program?
How has the MET program helped you?
Have your expectations of this program been met?

1. Employment plans

CAD Operator, R&B Machine Tool Co., $ 32 500 per year
DOW Chemical Corp., Midland Division (summer only)
Unsure of summer employment
Assembly Conveyor Systems, IT Equipment, $ 8.00 per hour (summer only)
Internship, Plant Engineering Department, American Bumper, Inc.
Truck Driver, Northern Lumber Company (summer only)
Unsure of summer employment
Drawform, Inc., full time
Looking for permanent employment
Attending Ferris during the summer
Brigadoon Golf Course, (summer only)
Assistant Machine Operator, Creative Techniques, $ 9.00 per hour (summer only)
Apprentice Electrician, LeFlair Electric Company, $ 8.50 per hour (summer only)
Newaygo County Road Commission, $ 6.50 per hour (summer only)
Unsure of summer employment

2. Further Education Plans

The plans these students have for further education are displayed in Table 4-3. 80 % plan to return to Ferris in Fall 1997; 20 % are going into full-time permanent employment. This is a typical MET class outcome. 53 % are headed for the product design program, while 27 % intend to enroll in the manufacturing or quality engineering technology programs.

TABLE 4-3
WHAT NEXT AFTER MET AAS

Option	Program	Number	Total	Percent
Work			2	13
Work and school			1	7
Attend Ferris			12	80
	PDET	8		
	MfgET	3		
	Quality Engineering Technology	1		
Other university			0	0

3. Reasons for Entering the MET Program

Responses to this question are tabulated in Appendix J. Notice the absence of references to family influence in choosing schools and programs. After two years of college, they seem to have cut the umbilical cord. This contrasts with data from first-year students shown in Table 4-1.

4. How students Have Been Helped by the MET Program

The students' explanations of how they have been helped by the MET program presented in Appendix J. The program has made a solid contribution to students' education in technical areas.

5. How Have Students' Expectations for the MET Program Been Met?

The responses concerning program expectations are tabulated in Appendix J.. The responses indicate that their expectations were met or were exceeded.

SECTION 5

FACULTY PERCEPTIONS

A. INTRODUCTION

Faculty perceptions: The purpose of this activity is to assess faculty perceptions regarding the following aspects of the program: curriculum, resources, admissions standards, degree of commitment by the administration, processes and procedures used, and their overall feelings. Additional items that may be unique to the program can be incorporated in this survey.

The Program Review in Occupational Education (PROE) system was employed. The MET program faculty developed a consensus response and the completed form is presented in Appendix K. The two essay questions are answered below.

B. PROE SURVEY RESPONSES: QUESTIONS 1 – 40

With one exception, the responses to the forty questions in the PROE survey are answered *good* (4) or *excellent* (5). Question 40 concerns provisions in capital outlay budget for equipment. Unfortunately, at Ferris there is no regular capital equipment budgeting or annual outlay for equipment repair and replacement.

All the programs in the College of Technology depend primarily on vocational-educational (Voc-Ed) funding from the State and Federal governments. As a two-year AAS program, MET qualifies for Voc-Ed support. We just have been awarded $ 13 000 in Voc-Ed funding. However, the criteria for funding awards changes from year to year and MET program often has not been funded.

Last spring we received an extra $ 6500 for materials and supplies (from salary savings disbursed by the Academic Affairs Office).

C. ESSAY QUESTION: WHAT ARE THE CHIEF OCCUPATIONAL EDUCATIONAL STRENGTHS OF YOUR PROGRAM?

(1) The MET program offers students an introduction into the fundamentals of applied science and technology. The technical courses feature hands-on laboratory-based instruction. Special emphasis is given to two areas: mechanical design and experimental testing. Upon completing the program, students have a number of viable options. They may seek employment as lab technicians or designers.

(2) Students also are well prepared for laddering into a number of engineering technology BS programs at Ferris, including product design, manufacturing, quality, and plastics.

(3) The MET program provides important support courses for a number of engineering technology programs in the College of Technology. These include engineering technology BS programs in electricity and electronics, manufacturing, plastics, product design, quality, and welding. Such courses include:

MECH 240 Statics & Strength of Materials (4 credits)
MECH 250 Fluid Power with Controls (2 credits)
CADD 490 Finite Element Analysis and Mold Flow (3 credits)

(4) The MET curriculum has been accredited by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc. (TAC of ABET). This action certifies that the MET curriculum, facilities and faculty meet national standards and criteria set in coordination with the American Society of Mechanical Engineers (ASME).

D. ESSAY QUESTION:
WHAT ARE THE MAJOR NEEDS FOR IMPROVEMENT IN YOUR PROGRAM AND WHAT ACTION IS REQUIRED TO ACHIEVE THESE IMPROVEMENTS?

(1) The immediate need in the MET program is faculty replacement. The replacement of Professor Olsson's tenure-track position has been authorized by the Board of Trustees, effective January 1998. A second tenure-track position, replacing a temporary full-time position, is being sought for Fall 1998. This will bring the MET faculty back to full strength.

(2) Needed for the MET laboratories is a regular equipment repair and replacement budget, as well as an annual capital equipment acquisition budget. This problem is shared with the rest of the programs in the College of Technology. Action is required at the University level.

(3) To get more money, several fund-raising efforts are underway. These include plans for an alumni fund raising effort to endow a scholarship, faculty development, and materials fund. Also in the planning stage is an industry capital fund drive. A leadership committee, consisting of officers of Michigan companies who have a Ferris connection, is being formed. Companies will be asked to equip (or re-equip) entire laboratories. These activities are being conducted in coordination with the Annual Giving/Development Services Office.

(4) Possibilities for curriculum initiatives at the four-year level need to be examined. A goal should be to establish an ABET-accredited, BS program relating to mechanical engineering technology. We have the facilities and the faculty. Why not the program? Traditionally, mechanical engineering (and mechanical engineering technology) has encompassed broad areas of application. These have included machine design, manufacturing, heat power, aeronautical, and experimental testing. Also, there are a number of hybrid BS possibilities: MET and plastics, MET and electrical, MET and manufacturing, and MET and design. By offering more options, we will attract more students.

(5) More effort needs to be devoted to program publicity and student recruitment The recent TAC of ABET accreditation helps make MET a marketable commodity and we should exploit it.

SECTION 6

INDUSTRY ADVISORY BOARD PERCEPTIONS

A. INTRODUCTION

Industry advisory board perception: *The purpose of this survey is to obtain information from the members of the program advisory committee regarding the curriculum, outcomes, facilities, equipment, graduates, micro- and mega-trends that might affect job placement (both positively and adversely), and other relevant information. Recommendations for improvement must be sought from this group.*

The MET program has an active Industry Advisory Board (IAB). They meet with MET program faculty and administrators on an annual basis. They were very supportive of the TAC of ABET accreditation effort. Four of them met with the visiting ABET evaluation team. Current Board membership is listed in Appendix L.

B. TABULATION OF SURVEY RESULTS

The survey form sent to the IAB members is reproduced as Appendix M. The results are presented in Table 6-1. There were eight respondents.

TABLE 6-1
INDUSTRY ADVISORY BOARD SURVEY FOR ACADEMIC PROGRAM REVIEW
RESPONSE DISTRIBUTION BY PERCENTAGES

Premise	Strongly Agree	Agree	Disagree	Strongly Disagree
1. The MET AAS Program provides education and training essential to many Michigan industries	88	13	0	0
2. The Program provides skills useful to your company	75	25	0	0
3. Your company would hire an MET program graduate	50	50	0	0
4. The Program curriculum is appropriate to industry needs	63	38	0	0
5. Laboratory facilities meet program needs	13	75	13	0
6. Program faculty have adequate academic credentials and industrial experience	88	13	0	0

C. COMPILATION OF INDUSTRY ADVISORY BOARD MEMBER COMMENTS

Comments and remarks contributed by the IAB members are listed below.

> "Outstanding program that provides necessary skills for future employment opportunities!"
> ... David Lampen, Customer Quality Manager

> "MET is an excellent foundation for a career in technology!"
> ... Cal Hemmeke, Technical Sales

"Most of my technical background came from Ferris State's mechanical engineering technology program. In industry, I have been qualified to do almost all tasks required from me with my AAS degree."

... Matt Potts, R&D Engineer

"Regarding program curriculum: As industry demands more and more skills, a two-year program's influence may diminish in the light of four-year graduates. Regarding laboratory facilities: I feel labs everywhere could always use more lab equipment and lab tools. The facilities do seem adequate."

... Paul Sims, Senior Project Engineer

"This is an excellent program. The faculty have worked over the years to make this a credible and highly desirable program. We would have no hesitation in hiring graduates of the program if suitable openings exist. Congratulations. And keep up the good work."

... Dr. Thiru Thiruvengadam, Project Manager

"We've had very good experiences with MET students in our summer work program. And we may actually be opening up a position at the company to hire a recent MET grad."

... Vincent Ursini, Senior Engineer

"With regard to program faculty and the retirement of George Olsson [issue of adequate faculty academic credentials and industrial experience]: This remains to be seen based on the credentials and experience of George's replacement. It probably will take two (2) instructors to replace him!"

... Jack Van Heest, Engineer

"Change is good. ABET is a start. Let's keep looking for feedback and challenge what we do today. We need to get ahead of the market in order to have a great program."

... [No attribution.]

SECTION 7

LABOR MARKET ANALYSIS

A. INTRODUCTION

Labor Market Demand Analysis: *This activity is designed to assess the marketability of future graduates. Reports from the Department of Labor and from industry are excellent sources for forecasting demand on graduates.*

The Reed City office of the State of Michigan Employment Security Agency supplied their latest career outlook publication.[1] This publication provided the data for our labor market analysis for mechanical engineering technology. Data for the State of Michigan from 1995, shown here in Table 7-1, explain why our students, in increasing numbers, are seeking four-year degrees.

TABLE 7-1
MEDIAN WEEKLY WAGE AND UNEMPLOYMENT RATES BY EDUCATIONAL ATTAINMENT - STATE OF MICHIGAN -- 1995

Education	Median Weekly Wage ($)	Unemployment Rate (%)
High School Dropouts	205	12.7
High School Diploma	400	6.0
Some College	430	3.9
College Degree	770	2.4

This explains why, year after year, about 80 % of students receiving their MET AAS degree ladder into BS degree programs. Their rewards in terms of increased lifetime earnings and improved job security are very significant.

The AAS degrees in engineering technology originated about forty years ago, in the mid-1950's. For several decades, such a degree was a starting point for a career in technology.

At Ferris, the introduction of the MET AAS program in 1970 was part of a trend. At that time most of the technology programs at Ferris ran for four consecutive quarters and granted certificates in subjects such as auto service, drafting, machine tool, and welding. In the decade 1977-1987, the certificate courses of study were all replaced by AAS degree programs. In addition, in a number of technical areas BS degree programs were started. These included engineering technology degrees in electricity and electronics, manufacturing, plastics, product design, and welding.

Although the product design BS program is a close cousin, no BS MET curriculum has been established. Nationwide, programs in mechanical, electrical and civil engineering technology have proved to be the most popular.

Thus, for the great majority of MET students, the program serves as a stepping-stone to a four-year technical BS degree. It might be thought that this should make the MET AAS degree obsolete. However, degree combinations, such as AAS MET plus BS manufacturing or plus product design or plus plastics, have proved to be popular with Michigan employers. The MET studies serve the role of a minor, or perhaps a second major. Successful completion of the foundation first and second years courses helps ensure success in years three and four.

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[1] "Michigan Career Outlook 2005." Michigan Employment Security Agency, Labor Market Research Unit, 7310 Woodward Avenue, Detroit, Michigan 48202

B. EMPLOYMENT OUTLOOK FOR MECHANICAL ENGINEERING TECHNICIANS AND TECHNOLOGISTS

MET AAS degree recipients are classified as "Mechanical engineering technicians and technologists."[2] The occupational description is:

> Assist mechanical engineers with problems related to the use, testing, and development of machinery and equipment (or systems) used in producing goods and services.

Related data pertaining to opportunities in the State of Michigan for mechanical engineering technicians and technologists include the following.

- Employment Growth Outlook: *Fast as average*
- Opening per Year: *130*
- Annual Salary Range: *$ 21 204 - $ 41 568*
- Suggested Education or Training: *On-the-Job-Training (OJT)*
  Vocational Training (VOC)
  Community Colleges (CC)
- Suggested Courses of Study: *Mechanical Technology*
  Robotics Technology
- Training Sites in Michigan: *Community Colleges*
  State Universities[3]*, including*
    - *Ferris State University*
    - *Lake Superior State University*[4]
    - *Michigan Technological University*
    - *Northern Michigan University*
    - *Saginaw Valley State University*
    - *University of Michigan – Dearborn*
    - *Wayne State University*
    - *Western Michigan University*

  Private Colleges and Universities

Based on the results of the MET alumni survey, graduates holding only AAS degrees typically are employed as technicians. Examples of job titles include Senior Technician (Nuclear power plant) and Instrument Maker (Cyclotron laboratory). Salaries reported by these alumni are in accord with the numbers listed above.

One contrast between the Ferris MET AAS program and others nationwide is its TAC of ABET accreditation. While many BS MET programs are ABET accredited, only about 30% of the two-year AAS programs have such accreditation.

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[2] *Ibid.,* page 25.

[3] At Eastern Michigan University there is a proposal to establish a four-year, TAC of ABET accredited, BS MET program, starting Fall 1998. There would be a design option and a manufacturing option.

[4] Recently, Lake Superior State University converted several of its engineering technology programs, including mechanical, into regular engineering programs.

C. EMPLOYMENT OUTLOOK FOR HOLDERS OF BS DEGREES IN ENGINEERING TECHNOLOGY

Employment data for holders of BS degrees in engineering technology is available from a number of sources. These include the MET alumni survey discussed in section 2 above, the Ferris Career Services surveys,[5] and by the TTC surveys also discussed in section 2. Conclusions that can be drawn from this information include the following.

- Starting salaries for engineering technologists with BS degrees typically are in the $ 30 000 to $ 35 000 range
- After 10 to 15 years of experience, the median salary exceeds $ 50 000. Higher salaries are obtained for those that acquire managerial responsibilities.
- As shown by the MET alumni survey, many acquire titles designating them as engineers. This aligns their pay scale with that for regular engineering BS graduates (see Appendix N).

Engineering technologists typically are employed in capital goods industries. In Michigan, the auto industry and its large network of suppliers employ the majority of our graduates. When the national economy is doing well, Michigan usually is doing even better. When a recession comes, Michigan typically is worse off than the national average. Consequently, employment in engineering technology (and in engineering) tends to suffer from booms and busts.

Because of the similarity in work assignments between BS engineering graduates and BS engineering technology graduates, it is useful to review the material presented in Appendix N. It summarizes the job outlook for mechanical engineers. The information presented also has relevance for engineering technologists with BS degrees.

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[5] *A Study of 1995-96 Graduates and Their Beginning Salaries.* Prepared by Career Services, Ferris State University, Big Rapids, Michigan 49307, July 1997.

SECTION 8

FACILITIES AND EQUIPMENT

A. INTRODUCTION

Evaluation of facilities and equipment: An analysis of present facilities and equipment as compared to program needs must be conducted. This analysis should also include an assessment of the availability to the program of technologies used in the workplace.

The facilities and equipment available to MET students are discussed and described in the attachments. The specific references include the following.

- The MET program laboratories are described in Attachment 2, Section 9, pages 9d-9g. An inventory of MET laboratory equipment is given in Appendix E.
- Computer facilities available to MET students are described in Attachment 2, Section 10, page 10a and Appendix F. A computer equipment upgrade for the MET measurements lab is mentioned in Attachment 3, Appendix J.

Assessments of the adequacy of the MET labs are contained in the student and the Industry Advisory Board surveys in Sections 2 and 6 of this report. Problems concerning capital equipment and repair and replacement budgeting are addressed by the faculty perceptions contained in Section 5.

Funding for the MET laboratories in 1997 has included the following sums.

$ 6500	from salary savings disbursed by the Academic Affairs Office
$ 13 000	Vocation Educational program funding
$ 1000	grant associated with attendance at the Ferris Faculty Summer Institute

The consensus judgement is that the MET laboratories meet student needs. The problem faced is how to insure needed funding for the future. This equipment budgeting problem needs to be faced at the University level.

SECTION 9

CURRICULUM EVALUATION

A. INTRODUCTION

<u>Curriculum review:</u> *The purpose of this activity is to determine through a comprehensive review of the curriculum whether it meets the needs of the market.*

An intensive curriculum review was conducted in conjunction with the TAC of ABET accreditation effort. The TAC of ABET standards for curriculums in mechanical engineering technology are developed in partnership with the American Society of Mechanical Engineers (ASME). A recent version of these criteria is reproduced in Appendix C. Revisions to the criteria are made on a regular basis. Thus, maintaining program accreditation status also insures conformance with updated national standards.

B. CURRICULUM REVISION FOR TAC OF ABET ACCREDITATION

Certain revisions were required to align the MET program curriculum with the TAC of ABET criteria. The curriculum proposal that was submitted to and approved by the Department, College, and University Curriculum committees appears in Attachment 2, Appendix B. The revised MET program check sheet took effect for students entering the program Fall 1996 and thereafter.

C. FUTURE MET CURRICULUM REVISIONS

A number of curriculum revision ideas are under consideration. It is judged that the MET labs are under-utilized. Thus, adding a one-credit, two-hour per week lab to the second and third semesters would intensify hands-on aspects of the program. A curriculum proposal along these lines is in preparation.

As discussed in earlier sections of this report, initiatives involving the establishment of TAC of ABET accredited BS programs relating to mechanical engineering technology should receive consideration. We have the facilities and the faculty (all being well with the current recruiting efforts), let's get the programs and the students.

SECTION 10

ENROLLMENT TRENDS

A. INTRODUCTION

Since its inception, the MET program has consisted of one section of first-year students and one section of second-year students. Twenty years ago the goal was to have 25 students enter in the Fall term of the first year and retain 15 students continue into the Fall term of the second year. The retention rate for the first year of the program was about 60 %. A smaller number of students completed the second year of the program and received their MET AAS degree. The total program enrollment fluctuated around 40. Program faculty were kept busy teaching support courses in drafting, descriptive geometry, fluid power, kinematics, and statics and strength of materials. Client programs included plastics, technical drafting, welding, manufacturing, and electrical.

The historical profile of the number of students completing the MET program each year is presented in Figure 2-1, page 2-2. The drop off in completions from 1985-1991 was caused by an increase in attrition rate rather than a decrease in MET admissions.

MET program enrollment trends and retention for the period 1992 – 1996 are discussed in Attachment 2, Section 10, pages 10a-10b.

B. EFFECT OF SEMESTER CONVERSION

Conversion from quarters to semesters at Ferris had a large impact on all programs across the campus. General education distribution requirements were increased and a 16 credit hour limit for full fees was established. This resulted in a credit-hour squeeze. The net effect on the MET program was the dropping of a second physics course and a technical calculus course. In addition, the first year of the program became more generic. The course in statics and strength of materials was moved to the second semester. This had the effect of opening up the second year of the program to transfer students from community colleges and elsewhere. Formerly, the MET program rarely received transfers.

C. EFFECT OF CURRICULUM REVISION FOR TAC OF ABET ACCREDITATION

In the curriculum revision instituted Fall 1996 to conform to accreditation requirements, a first-year materials course was dropped in favor of a second-year applied calculus course. This completed the establishment of a generic first-year course of study. The number of transfer students entering the second year of the MET program has increased from only one or two as recently as five years ago to 10 (out of 22) second year students. Our enrollment targets are now 35 Fall enrollees for the first year section and 25 for the second year. For Fall 1997, the numbers (including MET pre-technicals) add up to about 33 first-year and 22 second-year students.

D. PROBLEMS WITH THE COUNT

Counting students is a fine art. MET students fall into numerous categories:

Pre-technical students – They start the MET technical sequence the following school year

Regularly admitted students – No problem counting them

Students transferring into MET who are still listed with their former program

Students (typically in their second year) who have applied to enter a BS program at Ferris and are now listed as majoring in that program.

These counting problems can cause distortions in comparing program enrollments.

E. PROBLEMS WITH NON-COMPLETION OF THE MET AAS DEGREE

As can be seen in Figure 2-1, there has remained a gap between the number of students successfully completing the capstone course and the number each year receiving MET AAS diplomas. Typically, these students are missing an English class or a general education elective.

This problem has been compounded by BS programs that admit our MET students without requiring them to complete their AAS degree requirements first. This requirement had been the common in the past.

The issue of encouraging students to complete their MET AAS degree is discussed in Attachment 3, Section III, page III-1.

SECTION 11

PROGRAM PRODUCTIVITY

A. INTRODUCTION

Productivity information was obtained from the Office of Institutional Studies.[1] The tabulations are organized under University, College, Department, and course prefix headings. The data listings include the following.

Student Credit Hours (SCH)
Full Time Equated Faculty (FTEF)
Ratio of Student Credit Hours per Full time Equated Faculty (SCH/FTEF)

Ranked listings for the SCH/FTEF ratio are presented for the following categories.

College
Department
Course Prefix

Along with the listings, results are displayed as pie charts and bar graphs.

The MET program figures correspond to the MECH course prefix. Because of the recent College of Technology reorganization, the MECH prefix listings appear in two places. It was part of the Manufacturing Engineering Technologies department in the Fall 1993 - Winter 1996. Then it joined with the new Design, Manufacturing and Graphic Arts (DMGA) department in Fall 1996.

B. PRODUCTIVITY DATA FOR THE MET PROGRAM

The data for the MET program courses (MECH prefix) is presented in Tables 11-1 and 11-2.

TABLE 11-1
STUDENT CREDIT HOURS GENERATED BY THE MET PROGRAM

Year	Student Credit Hours (SCH)			
	Summer	Fall	Winter	Fall + Winter
1993-94	0	769	747	1516
1994-95	0	673	638	1311
1995-96	105	612	599	1211
1996-97	128	750	490	1240

Over the last four years, the mean (or average) values of student credit hours (SCH) generated, full time equivalent faculty (FTEF) and SCH/FTEF ratios for the MET program are as follows.

Mean Student Credit Hours per Year:	1320	± 219
Mean Full Time Equivalent Faculty:	2.82	± 0.69
Mean Ratio SCH/FTEF:	471	± 43

The ± values represent the bounds for a 95 % confidence interval for the mean values.

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[1] *Productivity Report, Fall 1993- Winter 1997.* Office of Institutional Studies, Ferris State University, Big Rapids, Michigan 49307.

TABLE 11-2
FULL TIME EQUATED FACULTY FOR THE MET PROGRAM

Year	Full Time Equated Faculty (FTEF)			
	Summer	Fall	Winter	Fall + Winter
1993-94	0	3.78	3.08	3.43
1994-95	0	2.60	2.79	2.70
1995-96	0.58	2.54	2.30	2.42
1996-97	0.67	2.73	2.72	2.72

TABLE 11-3
SCH/FTEF RATIO FOR THE MET PROGRAM

Year	SCH/FTEF RATIO[2]			
	Summer[3]	Fall	Winter	Fall + Winter
1993-94		204	243	442
1994-95		259	229	486
1995-96		241	260	500
1996-97		275	180	455

C. COMPARISON OF MET PROGRAM SCH/FTEF RATIO

The productivity report rank orders the Colleges, Departments and Programs within the University for the 1996-97 (Fall plus Winter) school year. The position of the of the MET program in the DMGA department and in the College of Technology is presented in Tables 11-4 and 11-5, respectively.

TABLE 11-4
DESIGN, MANUFACTURING AND GRAPHIC ARTS DEPARTMENT RANKING OF PROGRAMS BY SCH/FTEF RATIO FOR 1996-97[4]

Rank	Program Description	Course Prefix	SCH/FTEF[1] Ratio
1	Manufacturing Engineering Technology (BS)	MFGE	456
2	*Mechanical Engineering Technology (AAS)*	*MECH*	*455*
3	Technical Drafting and Tool Design (AAS)	TDTD	338
4	Manufacturing Tooling Technology (AAS)	MFGT	315
5	Plastics Engineering Technology (AAS & BS)	PLTS	306
6	Welding Engineering Technology (AAS & BS)	WELD	298
7	Product Design Engineering Technology (BS)	PDET	288
8	Printing Management (BS)	PMGT	213
9	Printing Technology (AAS)	PTEC	197
	DMGA Department (Aggregate)		324

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[2] The SCH/FTEF ratios presented here have been rounded off to the nearest whole number.

[3] SCH/FTEF ratios were not computer for Summer terms.

[4] Some course prefixes are not directly associated with programs. Examples include Engineering Graphics (ETEC) courses and Metallurgy (MATL) courses. These are omitted from the rankings.

TABLE 11-5
COLLEGE OF TECHNOLOGY
RANKING OF PROGRAMS BY SCH/FTEF RATIO FOR 1996-97[3]

Rank	Program Description	Course Prefix	SCH/FTEF[1] Ratio
1	Construction Management (BS)	CONM	487
2	Manufacturing Engineering Technology (BS)	MFGE	456
3	*Mechanical Engineering Technology (AAS)*	*MECH*	*455*
4	Civil Engineering Technology (AAS)	CETM	454
5	Automotive and Heavy Equipment Management	AHEM	421
6	Building Construction Technology (AAS)	BCTM	390
7	HVACR Engineering Technology (AAS and BS)	HVAC	380
8	Architectural Technology (AAS)	ARCH	360
9	Technical Drafting and Tool Design (AAS)	TDTD	338
10	Surveying Engineering (BS)	SURE	335
11	Electrical and Electronics Engineering Technology (AAS and BS)	EEET	319
12	Manufacturing Tooling Technology (AAS)	MFGT	315
13	Plastics Engineering Technology (AAS & BS)	PLTS	306
14	Heavy Equipment Service Engineering Technology (BS)	HSET	302
15	Automotive Service Technology (AAS)	AUTO	299
16	Welding Engineering Technology (AAS & BS)	WELD	298
17	Product Design Engineering Technology (BS)	PDET	288
18	Heavy Equipment Technology (AAS)	HEQT	285
19	Facilities Management (BS)	FMAN	233
20	Automotive Body (AAS)	ABOD	227
21	Printing Management (BS)	PMGT	213
22	Printing Technology (AAS)	PTEC	197
	College of Technology (Aggregate)		333
	Ferris State University (Aggregate)		447

Using the SCH/FTEF ratio from the 1996-97 school year as a productivity measure, we find that the MET program ranks second best out of nine programs in the DMGA department. Compared to other programs in the College of Technology, the MET program ranks third overall in productivity. MET productivity (Ratio = 455) also exceeds aggregate values for the DMGA department (324), for the College of Technology (333), and for the University (447).

SECTION 12

CONCLUSIONS

A. THE MET PROGRAM GOALS AND OBJECTIVES ARE CENTRAL TO THE FERRIS MISSION

The MET program provides the hands-on technical education central to the University's stated mission. Its graduates have productive careers in industry. Significant numbers of graduates are moving into leadership positions.

B. THE MET PROGRAM IS ACHIEVING UNIQUENESS AND IMPROVING ITS VISIBILITY

By securing accreditation by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc. (TAC of ABET), MET at Ferris joins a unique group of such programs nationwide. With its extensive laboratory facilities and well qualified and experienced faculty, it has established a strong position in technical education. Industry in Michigan increasingly looks to MET graduates as valuable employees.

C. THE MET PROGRAM PROVIDES IMPORTANT SERVICES TO THE STATE AND THE NATION

Services to state and nation are provided by MET alumni, faculty and students. The program provides service by generating a supply of well educated and trained technicians and engineering technologists. Graduates are advancing into industrial leadership positions and are helping build and improve the industrial base.

Faculty, along with their teaching duties, serve as consultants and make their knowledge base available to industry.

The students, through their student association, provide a number of services to the community. In particular, they volunteer to aid in enrichment programs for middle and secondary school students.

D. THE MET PROGRAM HAS BEEN IN DEMAND BY STUDENTS

The MET program admits one section of first-year students each Fall semester. Demand has been steady for the last decade. Typical first-year enrollment has been in the 28 to 38 range. There exists a network of former students, relatives, friends, employers, and co-workers that spread the word about the value of the MET program at Ferris. Many of the students arrive with clear educational goals. The MET program often is the key element in their plans.

E. THE QUALITY OF INSTRUCTION OFFERED BY THE MET PROGRAM IS EXCELLENT

There are a number of elements involved that promote the quality of the instruction for MET students. These include factors relating to curriculum, laboratories, faculty, and other resources of the College of Technology and the University.

The curriculum meets national standards set by TAC of ABET in coordination with the American Society of Mechanical Engineers (ASME). These standards are regularly reviewed and updated. The program will undergo periodic reviews to insure that these standards and criteria continue to be met.

The MET laboratories permit the student to enhance their classroom experiences. They explore technical applications of applied science with solids, liquids, gases, and electricity. They learn to work together as teams. They are expected to prepare laboratory reports. For their capstone projects, they make both oral and written presentations.

The MET faculty are well qualified. Present and past program faculty have had more than ten years industrial experience. Their academic credentials meet TAC of ABET standards.

The College of Technology provides computer resources available to all students. This has become an important part of the MET program course work.

F. THERE IS DEMAND FOR MET GRADUATES

Labor market studies show a steady demand in Michigan for technicians and engineering technologists. These graduates provide the technical talent necessary for the capital goods industries in Michigan and in the Mid-west. The Ferris Career Planning and Placement surveys show a high demand for College of Technology graduates in all fields.

Holders of AAS degrees in MET, without further education, typically become technicians. Labor market studies show that annual salaries fall in the range of $ 21 000 to $ 41 000. This includes both starting salaries and salaries achieved later on in their careers.

Holders of an AAS degree in MET plus a BS degree in engineering technology may expect a starting salary in the $ 30 000 to $ 35 000 range. For workers with 10 to 15 years of experience, the median annual salary exceeds $ 50 000.

G. THE MET PROGRAM PROVIDES ESSENTIAL SERVICES FOR OTHER PROGRAMS

The MET program offers service courses for a number of other programs. These include:

Electrical and Electronic Engineering Technology BS degree (electives in MET)
Manufacturing Engineering Technology BS degree (MECH 240)
Plastics Technology AAS degree program (MECH 250)
Plastics Engineering Technology (MECH 240, CADD 490)
Welding Engineering Technology BS degree (MECH 240)

These support courses serve as essential components of these programs.

H. THE MET PROGRAM HAS ADEQUATE LABORATORY FACILITIES AND EQUIPMENT

The laboratory facilities available to MET students include the following.

Machine shop (MFGT 150)
Computer labs (ETEC 140, MECH 122, all second-year courses)
Physics laboratory (PHYS 211, PHYS 212)
Fluid mechanics and fluid power lab (MECH 211)
Electrical and electronics lab (EEET 215)
Mechanical measurements lab (MECH 221)

These laboratories provide an excellent hands-on experience for the student. The lab activities complement and enhance the course textbook and lecture material.

Funding remains a problem. Although the MET labs have received significant support in the past, there remain problems in this area. The University does not have in place a regular budget for equipment repair and replacement. It also does not regularly budget for capital equipment acquisition.

The MET program has been fortunate in qualifying, from time-to-time, for vocational-technical education funds. This support comes from the state and federal governments. This year MET has been awarded $ 13 000. Last year, we did not qualify for funding.

I. THE MET PROGRAM HAS ADEQUATE LIBRARY INFORMATION RESOURCES.

The library resources available to the MET program and its students received considerable attention during the recent TAC of ABET accreditation evaluation. We responded by moving to upgrade the MET-related collection in the library. This was accomplished by securing the donation of a quantity of books and by implementing purchases through the "Yankee Book Peddler" system.

The electronic data bases acquired by the library are quite impressive. Students and faculty can initiate wide-ranging searches in technical subject areas. Also, construction of a new library building has been authorized and funded.

The MET program and the College of Technology are well served by its assigned liaison librarian.

An efforts needs to be made to maintain and upgrade the library's technology-related holdings

J. THE MET PROGRAM HAS A REASONABLE COST

The cost of the MET program has three basic components: faculty salaries and benefits, materials and supplies, and laboratory equipment repair and acquisition.

Regarding faculty labor costs, the MET program is a good bargain. The Office of Institutional Studies ranks program productivity by calculating the ratio of student credit hours generated to the number of full time equivalent faculty (SCH/FTEF). The MET program placed second out of 9 in the DMGA department and third overall in the College of Technology.

The materials and supplies budget is relatively modest for a technology program. The typical amount is about $ 6000 per year or less. The laboratory equipment acquisitions over the years have been made with funds acquired externally.

The TAC of ABET accreditation review incurred a one-time expense of about $ 10 000.

SECTION 13

RECOMMENDATIONS

A. PROGRAM STRENGTHS NEED TO BE MAINTAINED

1. Faculty Recruitment

The first priority is to recruit a qualified replacement for Professor Olsson. A tenure-track position, starting date January 1998, has been authorized by the Board of Trustees for this purpose. A search committee has been selected and advertisements have been placed.

Another MET faculty position should be sought for Fall 1998. This would restore the position once held by Professor Gillett. This will require a proposal and a petition to the DMGA department and College of Technology administration.

A full complement of qualified faculty will enable the MET program to meet its goals and objectives in the future.

2. Laboratory Equipment Funding

To meet future needs, regular funding is required for MET laboratory equipment repair and replacement as well as for capital equipment acquisition. The University needs to include these items as part of its annual budgeting process.

3. TAC of ABET Accreditation

The program should continue to meet the evolving standards and criteria set by our accrediting agency, TAC of ABET. These standards affect, for example, program curriculum, faculty credentials and development, entrance requirements, textbook selection and library holdings.

Application for re-accreditation should be made at the appropriate time.

B. SOME PROGRAM AREA NEED TO BE STRENGTHENED

1. Promotion and Publicity

With the program faculty back to full strength, resources should be made available to pursue program outreach. Industry contacts should be increased. Students should be aided in job searches on a systematic basis. The MET Industry Advisory Board (IAB) should continue to be employed in this effort.

2. Retention and Completion

Through the faculty advising role, students' progress through the program should be monitored. Upon the first signs of difficulty, the advisors should seek to obtain aid for their advisees. Increased focus should be given to meeting all AAS degree graduation requirements in a timely fashion.

C. CURRICULUM INITIATIVES NEED TO BE EXPLORED

1. Revisions of the present MET curriculum

In the aftermath of the TAC of ABET accreditation process, curriculum review should continue. Attention should be given to increasing the utilization of the MET laboratories.

2. Investigation of accredited BS degree options

A number of possibilities exist for new curriculum initiatives in the MET area. These include the development of accredited four-year BS degree program in engineering technology. Possibilities should be explored for hybrid programs, such as mechanical and plastics, mechanical and rubber technology, mechanical and electrical, and so forth.

REFERENCES[1,2]

1. *College of Technology Alumni Survey 1995.*
2. *Michigan Career Outlook 2005.* Michigan Employment Security Agency, Labor Market Research Unit. 7310 Woodward Avenue, Detroit, Michigan 48202.
3. *Ferris State University Fact Book 1995-96.*
4. *Ferris State University Fact Book 1996-97.*
5. "Achieving Academic Success - A Plan for Assessing Academic Outcomes." December, 1995.
6. *Ferris State University Catalog 1995-97*
7. *A Study of 1994 - 1995 Graduates and Their Beginning Salaries.* Career Planning and Placement.
8. [Promotional Brochures] Mechanical Engineering Technology Program.
9. "Proposal for a Bachelor of Science Degree Program in Mechanical Engineering Technology" by the Faculty of the Department of Industrial Technology in the College of Technology. Eastern Michigan University, Ypsilanti Michigan, November 27, 1996.
10. *Productivity Report, Fall 1993 - Winter 1997.* Office of Institutional Studies.

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[1] Unless otherwise indicated, the document source is Ferris State University, Big Rapids, Michigan 49307.

[2] A number of other sources of information are contained in the Appendixes of this report and of Attachments 1-3.

TOPICAL INDEX

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[1] Nos. 1-5 designate the attachments; *APR* refers to this volume.

APPENDIX A

ACADEMIC PROGRAM REVIEW: A GUIDE FOR PARTICIPANTS

ACADEMIC PROGRAM REVIEW: A GUIDE FOR PARTICIPANTS

OFFICE OF ACADEMIC AFFAIRS/
ACADEMIC SENATE
FERRIS STATE UNIVERSITY
BIG RAPIDS, MICHIGAN 49307

June 1996

ACADEMIC PROGRAM REVIEW: A GUIDE FOR PARTICIPANTS

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Introduction

Appendices

Mechanical Engineering Technology
APRC 1997-1998

Section 2 of 4

I. ACADEMIC PROGRAM REVIEW COUNCIL

Members of the Academic Program Review Council (APRC) are appointed for two-year terms by the Executive Committee of the Academic Senate. The Council shall include the following:

1. Ten tenured faculty members: one from each college, one from the librarians/counselors unit, and two at large. No more than two faculty members from any one college should serve on APRC.

2. Two academic administrators appointed by the Provost/Vice President for Academic Affairs, *ex officio*: deans, directors, associate or assistant deans, department heads or chairs, or program directors.

The APRC Chair is appointed by the Executive Committee of the Academic Senate for a one-year term. Only voting members of APRC can serve as Chair.

APRC normally operates as a committee of the whole. To facilitate timely and effective review, however, APRC can at its discretion divide itself into subcommittees. Though some reviewing work may be split among subcommittees, decisions made by the subcommittees will be ratified by APRC as a whole.

II. REVIEW SCHEDULE

In consultation with the colleges, the Provost/VPAA will prepare a schedule listing the programs to be reviewed over a six-year period beginning in the fall of 1996. (The current review schedule will constitute Appendix D in the program review manual.) Programs with curricular links (for example, associate and baccalaureate programs in the same area, or all teacher education programs) can be combined into a single review. Reviews of programs with external accrediting bodies should be scheduled so that the work done can be used for both institutional and external reviews. As much as possible, the reviews should be evenly spaced over the six years of the cycle. During the sixth year of each cycle, the Provost/VPAA should prepare a new schedule for the next six-year cycle. The Provost/VPAA will add new programs into the cycle as they are approved.

III. REVIEW OUTSIDE THE SCHEDULE

At least three years since the completion of the last review must pass before a program can be reviewed again. Should circumstances arise such that an unscheduled review is thought to be necessary, such a review can be requested by either the faculty or the Provost/VPAA. Programs can be proposed annually by the Provost/VPAA for unscheduled review. Appropriate justification and documentation supporting the need for review must reach APRC at least a semester in advance of the beginning of the annual review cycle. The programs selected for unscheduled review by APRC can come only from lists submitted by the faculty and the Provost/VPAA. APRC must advise the

Provost/VPAA, the Academic Senate President, and the program faculty of its decision to make an unscheduled review at least half a semester prior to the beginning of the annual program review cycle.

APRC's decision to **allow** an unscheduled review of a program is final and cannot be appealed. However, if APRC does not agree to at least one unscheduled review, it must justify its **refusal** to the Academic Senate. The Academic Senate can override APRC's **refusal** to make an unscheduled review.

If the Academic Senate concurs with APRC's **refusal** to make an unscheduled program review, it must advise the University President of its decision at least four weeks prior to the beginning of the annual program review cycle. The University President can override this **refusal** and a review will be scheduled. This decision must be made within two weeks of the beginning of the annual program review cycle.

IV. ADMINISTRATIVE PROGRAM REVIEW

An effective program review process is not possible without a reliable data base. It is essential that a profile be maintained for every academic program in the University. Through the offices of the deans and department heads, the Provost/VPAA will annually prepare a profile of each academic program. This information (see Appendix A: Administrative Program Review) will be updated annually.

V. THE PROGRAM REVIEW PANEL

A Program Review Panel (PRP) is formed for each program or cluster of programs scheduled for review. The panel shall consist of the following:

1. A faculty member, preferably tenured and from the program, to chair the PRP. APRC will seek the advice of the department head and faculty in appointing the chair.
2. The program director or coordinator, or the head of the department in which the program is located.
3. Two program faculty, where possible.
4. An individual with special interest in the program. This person could be an alumnus(a), an advisory committee member, an adjunct faculty member, or an interested faculty member from outside the program.
5. A faculty member from outside the college.

APRC appoints the PRP Chair, with the advice of the department head and faculty. The PRP Chair, with the advice of the department head and faculty, appoints the remainder of the PRP. The names of PRP members should be submitted to APRC as soon as the panel is formed.

VI. PLAN AND SURVEY INSTRUMENTS

The Program Review Panel (PRP) will meet as soon as possible after its formation to undertake the following tasks:

1. Review the information contained in the administrative program review document (Appendix A).

2. Develop a statement in which the purpose and scope of the review are articulated.

3. Assign a leader and a target date for each of the following activities (see Appendix E):

    - Graduate follow-up survey
    - Employer follow-up survey
    - Student evaluation of program
    - Faculty perceptions of program
    - Advisory committee perceptions of program
    - Labor market analysis
    - Evaluation of facilities and equipment
    - Curriculum evaluation

    The survey instruments should be chosen or designed to reflect general aspects of program review as well as the specific nature of the program itself.

4. Determine the number of individuals in each category to be surveyed. It is important that the results of the surveys be statistically valid.

5. Determine data collection techniques and information sources.

The PRP chair shall submit to APRC an evaluation plan (Appendix F). APRC will review the plan using criteria of soundness and ability to generate sufficient data to support conclusions. Plan deficiencies will be worked out by the chairs of APRC and the PRP.

VII. BUDGET

The Provost/VPAA will annually set aside funds specifically designated for program review purposes. Along with its evaluation plan, the PRP should also submit to APRC a budget that should cover the expenses the panel incurs in the process of gathering data and preparing the report (Appendix F). Typically these expenses include such items as copying, telephone, clerical, and postage. After APRC and the Provost/VPAA's office have approved a budget, the necessary funds will be transferred from Academic Affairs into the account from which the department will pay the expenses of the review.

VIII. PRP REPORT

The PRP will conduct its review in accordance with the approved plan and will submit its report to the APRC. The dean of the college should also receive a copy of the report. The dean should send his or her comments on the report to APRC.

The report should include the following elements:

1. Section 1: an overview of the program that addresses broadly the areas of the program included in the academic program review document (Appendix A). This section should acquaint the reader with the program: mission, history, impact (on the university, state, and nation), expectations, plans for improvement, and any other items that would help the reader fully appreciate the remainder of the report.

2. Sections 2 through 9: results and analysis of data collected during the eight activities listed following item 3 under PLAN AND SURVEY INSTRUMENTS. These sections must include, among others, techniques used in collecting the information, difficulties encountered during the surveying process, percent of respondents, and analysis of data in accordance with established methodologies.

3. Section 10: enrollment trends over the past five years.

4. Section 11: program productivity /cost.

5. Section 12: conclusions based on data analysis derived from Sections 2-11 and on the collective wisdom and judgment of the PRP. In arriving at these conclusions, the PRP should use the following specific criteria and any other criteria it deems appropriate:

    - Centrality to FSU mission
    - Uniqueness and visibility
    - Service to state and nation
    - Demand by students
    - Quality of instruction
    - Demand for graduates
    - Placement rate and average salary of graduates
    - Service to non-majors
    - Facilities and equipment
    - Library information resources
    - Cost

- Faculty: professional and scholarly activities
- Administration effectiveness

6. Section 13: recommendations derived from the conclusions of Section 12. They must address the program's strengths and weaknesses. Objectivity and candor are the cornerstones of this section. The panel should bear in mind as it formulates its recommendations the program's potential for growth, its stability, or its present or pending decline. Suggested measures and actions should be specific and clear.

   This section of the report should also include an evaluation form (Appendix I) completed by the PRP. An average score is assigned for each part of the form. Each member of the PRP should complete the form independently and anonymously.

IX. APRC REVIEW OF THE PRP REPORT

After APRC reviews and analyzes the PRP report and the college dean's comments, the Council will meet with members of the PRP to discuss the report. Unless the PRP objects, the college dean will be invited to this meeting. If necessary, a separate meeting will be held with the college dean.

X. APRC RECOMMENDATION

APRC will submit to the Academic Senate President its recommendation regarding the program under review. The recommendation should do the following:

1. Assign one of the categories in Appendix H to the program with respect to its future status.

2. Articulate the determinants which involved the assignment of a particular category to the program. The strengths and deficiencies of the program should be elucidated in such a fashion that their impact in arriving at the assigned category is clear.

3. In cases other than discontinuation of the program, specify actions needed to correct the weaknesses of the program and enhance its strengths. Additionally, measures to be taken that are consistent with the assigned category must be presented. In the case of a program slated for enhancement, APRC should specifically state the actions it recommends to arrive at such an outcome.

The PRP chair, the college dean, and the Provost/VPAA shall receive copies of the APRC's recommendations at this time.

XI. ACADEMIC SENATE RECOMMENDATION

The Academic Senate will discuss the recommendation submitted by APRC, along with any written rebuttal from the PRP. At the conclusion of Academic Senate deliberations on each program, the Academic Senate President should submit the Senate's recommendation to the Provost/VPAA.

XII. PROVOST/VPAA RECOMMENDATION

The Provost/VPAA will review the recommendations of the Academic Senate, the PRP report, and any other relevant documentation compiled during the APRC and Academic Senate deliberations. Prior to sending his or her recommendation to the University President, the Provost/VPAA may choose to discuss the recommendation in a meeting with the Academic Senate Executive Committee. No recommendation can come from the Executive Committee that is different from the one voted by the Academic Senate.

XIII. UNIVERSITY PRESIDENT RECOMMENDATION

The University President may accept the recommendation of the Provost/VPAA or disagree with it. He or she must inform the Academic Senate President of his decision regarding the program under review. **If** the University President's decision is in conflict with the Academic Senate's recommendation **and if** the decision involves the reduction or discontinuation of a program, a conference committee shall be formed in accordance with Section 8 of the charter of the Academic Senate.

XIV. ACTION PLANS

For programs to be continued, enhanced, monitored, or redirected:

1. The college dean and the administration and faculty of the program will develop an action plan addressing the needs of the program and delineating the expectations from it. Budget and resources to fulfill the objectives of the plan must be specified.

2. The Provost/VPAA, Academic Senate President, and APRC Chair shall meet to review and discuss the plan/budget.

3. The Provost/VPAA shall approve the plan/budget with or without modification.

4. APRC is responsible for monitoring the implementation of the action plan. This

includes taking appropriate measures based on outcomes specified in the plan. APRC shall make periodic progress reports to the Academic Senate concerning the action plan for each program.

For programs to be reduced or discontinued:

1. The Provost/VPAA and the college dean will develop an action plan. The plan must specify a timeline and the stages through which the program is to be reduced or discontinued.

2. APRC will review the action plan to assure the process is being carried out in a timely fashion so that the students enrolled in the program are not adversely affected.

3. The final plan will require approval by the Academic Senate.

APPENDIX A
ADMINISTRATIVE PROGRAM REVIEW

Program/Department: ______________________________

Date Submitted: ____________________ Dean: ______________________

Please provide the following information:

	Fall 1992	Fall 1993	Fall 1994	Fall 1995	Fall 1996
Tenure Track FTE					
Overload/Supplemental FTEF					
Adjunct/Clinical FTEF (unpaid)					
Enrollment on-campus total*					
Freshman					
Sophomore					
Junior					
Senior					
Masters					
Doctoral					
Enrollment off-campus*					

*Use official count (7-day count for semesters, 5-day count for quarters).

Financial

Expenditures*	FY 92	FY 93	FY 94	FY 95	FY 96
Supply & Expense					
Equipment					
Gifts & Grants					

*Use end of fiscal year expenditures.

Other

	AY 91/92	AY 92/93	AY 93/94	AY 94/95	AY 95/96
Number of Graduates* - Total					
- On campus					
- Off campus					
Placement of Graduates					
Average Salary					
Productivity - Academic Year Average					
- Summer					
Summer Enrollment					

* Use total for academic year (F, W, S)

1. a. Areas of Strengths:

1. b. Areas of Concern:

2. Future goals (please give time frame)

3. Recommendations:

APPENDIX B
ACADEMIC PROGRAM REVIEW
1996-1997 CALENDAR

1996

May 1	**Program Review Panel Chair appointed; PRP formed**
May 15	**PRP begins to meet**
June 15	**Evaluation Plan and Budget submitted to APRC**
July 15	**Chairs of PRP and APRC complete revised plan (if needed)**
August 1	**Revised Plan submitted to APRC**
Aug. - Oct.	Surveys developed and sent out
Nov. - Dec.	Data collected and report written
December 15	PRP report submitted
February 15	APRC forwards recommendations to Academic Senate
March 1	Academic Senate submits recommendations to Provost/Vice President for Academic Affairs
March 10	Provost/Vice President discusses his/her recommendations with Senate Executive Committee
March 15	Provost/Vice President forward his/her recommendations to University President
March 22	University President informs Academic Senate President of his/her decision.
March 25	Conference Committee formed (if needed)
April 1	Dean and administration/faculty of program submit an action plan to Provost/Vice President
April 8	Provost/Vice President, Academic Senate President, and APRC Chair meet to review plans
April 15	Provost/Vice President approves final version of action plans

Approved by Academic Senate June 20, 1996

APPENDIX C
ACADEMIC PROGRAM REVIEW
1997-1998 CALENDAR

1996

November 1	Program Review Panel Chair appointed; PRP formed
November 15	PRP begins to meet
December 15	Evaluation Plan and Budget submitted to APRC

1997

January 20	Chairs of PRP and APRC complete revised plan (if needed)
February 1	Revised Plan submitted to APRC
Feb.- Apr.	Surveys developed and sent out
May - Sept.	Data collected and report written
September 15	PRP report submitted
November 1	APRC forwards recommendations to Academic Senate
November 15	Academic Senate submits recommendations to Provost/Vice President for Academic Affairs
November 22	Provost/Vice President discusses his/her recommendations with Senate Executive Board
December 1	Provost/Vice President forwards his/her recommendations to University President
December 8	University President informs Academic Senate President of his/her decision
December 10	Conference Committee formed (if needed)
December 15	Dean and administration/faculty of program submit an action plan to Provost/Vice President
January 8	Provost/Vice President, Academic Senate President, and APRC Chair meet to review plans
January 15	Provost/Vice President approves final version of action plans

APPENDIX D

ACADEMIC AFFAIRS

Program Review Cycle

1997-2003

__1997-98__
1. Dental Hygiene (A.A.S.)
2. Dental Technology (A.A.S.)
3. Industrial/Environmental Health Management (B.S.)
4. Nursing (B.S.N.)
5. Applied Biology (B.S.)
6. General Business (A.A.S.) and Real Estate (B.S.)
7. Advertising (B.S.) and Public Relations (B.S.)
8. Recreation Leadership and Management (B.S.)
9. Mechanical Engineering Technology (A.A.S.)
10. Tech Drafting/Tool Design (A.A.S.)
11. Applied Math and Actuarial Science (B.S.)
12. Opticianry (A.A.S.)
13. Teacher Education (M.S. Ed., B.S., A.A.) progress report due on March 15, 1998 as required by 1996-97 APRC review recommendations.

__1998-99__
1. Technical And Professional Communication (B.S.)
2. Finance (B.S.) and Accountancy/Finance (B.S.)
3. Accountancy Programs (B.S. and M.S.)
4. Management (B.S.)
5. Information Systems Management (M.S.)
6. Visual Communications (A.A.S. and B.S.)
7. Optometry (O.D.) and Visual Science (B.S.)
8. Pharmacy (B.S.)
9. Television Production (B.S.)
10. Heavy Equipment Technology (A.A.S.) and Heavy Equipment Service Engineering Technology (B.S.)
11. Construction Management (B.S.), Building Construction Technology (A.A.S.) and Civil Engineering Technology (A.A.S.)
12. Manufacturing Engineering Technology (B.S.) and Manufacturing Tooling Technology (A.A.S.)
13. Biotechnology (B.S.)
14. Radiography (A.A.S.) program review as required by 1996-97 APRC review recommendation.
15. Insurance (B.S.) and Insurance/Real Estate (B.S.) progress report due on March 15, 1999 as required by 1996-97 APRC review recommendation.

__1999-00__
1. Medical Laboratory Technology and Medical Technology (A.A.S. and B.S.)
2. Ornamental Horticulture Technology (A.A.S.)
3. Child Development (A.A.S.)
4. Human Resource Management (B.S.)
5. Operations Management (B.S.)
6. Management/CIS (B.S.) and Computer Information Systems (B.S.)

7. Marketing/Sales (B.S.)
8. Automotive Body (A.A.S.)
9. Facilities Management (B.S.) and Architectural Technology (A.A.S.)
10. Public Administration (B.S.)
11. Printing Management (B.S.) and Printing Technology (A.A.S.) progress report on enrollment is due on October 1, 1999 as required by the 1996-97 APRC review recommendations.

<u>2000-01</u>

1. Health Care Systems Administration (B.S.), Health Information Management (B.S.) and Health Information Technology (A.A.S.)
2. Nursing (A.A.S.)
3. Business Administration (B.S.)
4. International Business (B.S.) and Small Business Management (B.S.)
5. Quality and Productivity Management (B.S.)
6. Music Industry Management (B.S.)
7. Product Design Engineering Technology (B.S.)
8. Surveying Engineering (B.S.) and Surveying Technology (A.A.S.)
9. HVACR Technology (A.A.S.) and HVACR Engineering Technology (B.S.)
10. Auto/Heavy Equipment Management (B.S.)
11. English Education (B.S.)

<u>2001-02</u>

1. Industrial Chemical Technology (A.A.S.)
2. Social Work (B.S.)
3. Legal Assistant (A.A.S.)
4. Food Service (A.A.S.)/Hospitality Management (B.S.)
5. Retailing (A.A.S. and B.S.)
6. Criminal Justice (B.S.)
7. Pharmacy (Pharm. D.)
8. Computer Networks and Systems (B.S.)
9. Quality Engineering Technology (B.S.)
10. Electrical/Electronics Technology (B.S.) and Industrial Electronics Tech (A.A.S.)
11. Criminal Justice Administration (M.S.)
12. Applied Speech Communication (A.A.S. and B.S.)

<u>2002-03</u>

1. Nuclear Medicine (A.A.S. and B.S.)
2. Radiography (A.A.S.)
3. Respiratory Care (A.A.S.)
4. Insurance (B.S.) and Insurance/Real Estate (B.S.)
5. Professional Golf Management (B.S.)
6. Professional Tennis Management (B.S.)
7. Teacher Education (M.S. Ed., B.S., A.A.)
8. Automotive Service Technology (A.A.S.)
9. Plastics Technology (A.A.S. and B.S.)
10. Printing Technology (A.A.S.) and Printing Management (B.S.)
11. Welding Technology (A.A.S. & B.S.)

Revised May 28, 1998

Appendix E
Data Collection Activities

Graduate follow-up survey: The purpose of this activity is to learn from the graduates their perceptions and experiences regarding employment based on program outcomes. The goal is to assess the effectiveness of the program in terms of job placement and preparedness of the graduate for the marketplace. A mailed questionnaire is most preferred; however, under certain conditions telephone or personal interviews can be used to gather the data.

Employer follow-up survey: This activity is intended to aid in assessing the employers' experiences with graduates and their perceptions of the program itself. A mailed instrument should be used to conduct the survey; however, if justified, telephone or personal interviews may suffice.

Student evaluation of instruction: Students are surveyed to obtain information regarding quality of instruction, relevance of courses, satisfaction with program outcomes based on their own expectations. The survey must seek student suggestions on ways to improve the effectiveness of the program and to enhance the fulfillment of their expectations.

Faculty perceptions: The purpose of this activity is to assess faculty perceptions regarding the following aspects of the program: curriculum, resources, admissions standards, degree of commitment by the administration, processes and procedures used, and their overall feelings. Additional items that may be unique to the program can be incorporated in this survey.

Advisory committee perceptions: The purpose of this survey is to obtain information from the members of the program advisory committee regarding the curriculum, outcomes, facilities, equipment, graduates, micro- and megatrends that might affect job placement (both positively and adversely), and other relevant information. Recommendations for improvement must be sought from this group. In the event that a program does not have an advisory committee, a group of individuals may be identified to serve in that capacity on a temporary basis.

Labor market demand analysis: This activity is designed to asses the marketability of future graduates. Reports from the Department of Labor and from industry are excellent sources for forecasting demand on graduates.

Evaluation of facilities and equipment: An analysis of present facilities and equipment as compared to program needs must be conducted. This analysis should also include an assessment of the availability to the program of technologies used in the workplace.

Curriculum review: The purpose of this activity is to determine through a comprehensive review of the curriculum whether it meets the needs of the market.

Appendix F

Evaluation Plan Format

Program: ____________________

Degrees Awarded by Program: ____________________

Purpose:

Data Collection Techniques and Information Sources:

Schedule of Events:

Activity	Leader	Target Dates

Signature of Program Review Panel Chair: ____________________

SAMPLE EVALUATION PLAN

PROGRAM EVALUATION PLAN
LEGAL ASSISTANT PROGRAM

Degrees Awarded: A.A.S. in Legal Assisting

Program Review Panel:

Chair and Program Coordinator: John Kane
Program faculty and Assistant Coordinator: John Vermeer
College of Business faculty: Michael Cooper
Individual with special interest in the Program: R. Dale Hobart
Faculty member outside the College of Business: Sally Krumins
Management Department Chair: Vivian Nazar

Purpose: To conduct a study of the Legal Assistant Program to evaluate its needs and effectiveness so the University can make informed decisions about resource allocations.

Data Collection Techniques

1. Graduate surveys completed in 1989 and 1994
2. Employer surveys from 1995
3. Student evaluation of program and courses from 1994 and 1995
4. Faculty perception of program from surveys to both Legal Assistant faculty and College of Business faculty.
5. Advisory Committee perceptions of the program from questionnaire to advisory board members.
6. Labor Market analysis information from current market indictors.
7. Evaluation of facilities and equipment by doing a review of the law collection in the library, the adequacy of classrooms and computer facilities.
8. Curriculum evaluation information will be taken from the American Bar Association self-study completed in 1995 and the ABA assessment of that information.

Schedule of Events

Activity	Leader	Target Date
Graduate Survey	Kane	November 15
Employer Survey	Kane	November 15
Student Evaluation	Vermeer	December 1
Faculty Perceptions of Program	Vermeer	December 1
Advisory Committee Perceptions	Kane	December 1
Labor Market Analysis	Krumins	December 1
Evaluation of Facilities	Krumins	December 1
Curriculum Evaluation	Kane	December 1

SAMPLE BUDGET

MEMORANDUM

TO: Doug Haneline, Chair, Academic Program Review Committee

FROM: Bill Killian, Associate Professor, Industrial Chemistry Technology Program
Dave Frank, Department Head, Physical Sciences

SUBJECT: Proposed budget for Industrial Chemistry Technology program review panel

DATE: October 30, 1995

Below is a copy of our proposed budget for the Industrial Chemistry Technology review panel. Please contact us if you have any questions.

Student Surveys (375)	
Copying Costs	$ 28.13
Mailing Costs	206.25
Return Envelope Printing	25.50
Return Mailing Costs	146.25
Advisory Board Surveys	
Copying and Mailing	7.00
Student Wage Support	
40 Hours at $4.25/hour	170.00
Phone Expenses	50.00
Final Document Copying Costs	90.00
TOTAL	$ 723.13

Appendix H

Program Review Rating Categories

Continue the program: The program meets or exceed all criteria and the job placement is sound or the curriculum is unique in the State of Michigan. Minor modifications may be needed.

Enhance the program: The program meets or exceeds all criteria and it warrants expansion in enrollment to meet the human resources needs in the State of Michigan. A program enhancement may involve additional faculty/staff, equipment, or other resources and/or expansion in enrollment. However, such an expansion would not be initiated without the allocation of resources needed to maintain quality with an enlarged student body.

Continue the program with monitoring: Documented problem areas exist in a basically sound program that warrants continuation. The faculty and administration of the program will be monitored as to their progress in solving these problems.

Continuing the program with redirection: Significant documented problems exist within the curriculum which should be addressed. Curricular revision (redirection) in accordance with accepted University policies and procedures will be undertaken by the faculty and administration of the program. The recommendations for redirection must be submitted as a part of the final program review report.

Reduce the program: The program meets or exceeds many of the criteria, but does not claim a unique position in the State of Michigan, the job market for its graduates is diminishing, or the enrollments is declining precipitously. It should, therefore, be reduced in enrollment or resources.

Discontinue the program: Evidence suggests that the program should be terminated.

Appendix I

PROGRAM REVIEW PANEL EVALUATION

Program: ____

Instructions: Circle the number which most closely describes t he program you are evaluating.

1. **Student Perception of Instruction** **Average Score** _______

5 4 3 2 1

Currently enrolled students rate instructional effectiveness as extremely high.	Currently enrolled students rate the instructional effectiveness as below average.

2. **Student Satisfaction with Program** **Average Score** _______

5 4 3 2 1

Currently enrolled students are very satisfied with the program faculty, equipment, facilities, and curriculum.	Currently enrolled students are not satisfied with program faculty, equipment, facilities, or curriculum.

3. **Advisory Committee Perceptions of Program** **Average Score** _______

5 4 3 2 1

Advisory committee members perceive the program curriculum, facilities, and equipment to be of the highest quality.	Advisory committee members perceive the program curriculum, facilities, and equipment needs improvement.

4. **Demand for Graduates** **Average Score** _________

5 4 3 2 1

Graduates easily find employment in field.	Graduates are sometimes forced to find positions out of their field.

5. **Use of Information on Labor Market** **Average Score** _________

5 4 3 2 1

The faculty and administrators use current data on labor market needs and emerging trends in job openings to systematically develop and evaluate the program.	The faculty and administrators do not use labor market data in planning or evaluating the program.

6. Use of Profession/Industry Standards **Average Score __________**

5	4	3	2	1
Profession/industry standards (such as licensing, certification, accreditation) are consistently used in planning and evaluating this program and content of its courses.				Little or no recognition is given to specific profession/industry standards in planning and evaluating this program.

7. Use of Student Follow-up Information **Average Score __________**

5	4	3	2	1
Current follow-up data on completers and leavers are consistently and systematically used in evaluating this program.				Student follow-up information has not been collected for use in evaluating this program.

8. Relevance of Supportive Courses **Average Score __________**

5	4	3	2	1
Applicable supportive courses are closely coordinated with this program and are kept relevant to program goals and current to the needs of students.				Supportive course content reflects no planned approach to meeting needs of students in this program.

9. Qualifications of Administrators and Supervisors **Average Score __________**

5	4	3	2	1
All persons responsible for directing and coordinating this program demonstrate a high level of administrative ability.				Persons responsible for directing and coordinating this program have little administrative training and experience.

10. Instructional Staffing **Average Score __________**

5	4	3	2	1
Instructional staffing for this program is sufficient to permit optimum program effectiveness.				Staffing is inadequate to meet the needs of this program effectively.

11. Facilities **Average Score __________**

5	4	3	2	1
Present facilities are sufficient to support a high quality program.				Present facilities are a major problem for program quality.

12. Scheduling of Instructional Facilities

Average Score ________

5 4 3 2 1

Scheduling of facilities and equipment for this program is planned to maximize use and be consistent with quality instruction.	Facilities and equipment for this are significantly under-or-over scheduled.

13. Equipment

Average Score ________

5 4 3 2 1

Present equipment is sufficient to support a high quality program.	Present equipment is not adequate and represents a threat to program quality.

14. Adaption of Instruction

Average Score ________

5 4 3 2 1

Instruction in all courses required for this program recognizes and responds to individual student interests, learning styles, skills, and abilities through a variety of instructional methods (such as, small group or individualized instruction, laboratory or "hands on" experiences, credit by examination).	Instructional approaches in this program do no consider individual student differences.

15. Adequate and Availability of Instructional Materials and Supplies

Average Score ________

5 4 3 2 1

Faculty rate that the instructional materials and supplies as being readily available and in sufficient quantity to support quality instruction.	Faculty rate that the instructional materials are limited in amount, generally outdated, and lack relevance to program and student needs.

APPENDIX A

FERRIS STATE UNIVERSITY
ACADEMIC PROGRAM REVIEW COUNCIL
PROGRAM REVIEW PANEL REPORT ANALYSIS SHEET

Date:

Program Name: Mechanical Engineering Technology AAS Program

Program Review Rating Criteria:

- Centrality to FSU Mission
- Uniqueness and visibility
- Service to State and Nation
- Demand by students
- Quality of instruction
- Demand for graduates
- Placement rate and average salary of graduates
- Service to non-majors
- Facilities and equipment
- Library information resources
- Cost
- Faculty: Professional and scholarly activities
- Administration effectiveness

Program Review Rating Categories:

- Continue the program
- Enhance the program
- Continue the program with monitoring

APRC members: Use this sheet to make notes on the reports of the programs under review

APPENDIX B

ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY, INC.

GEORGE D. PETERSON, Ph.D. P.E.
Executive Director

September 4, 1997

William Sederburg
President
Ferris State University
1349 Cramer Circle
Bishop Hall, 421E
Big Rapids MI 49307

Dear Dr. Sederburg:

The Technology Accreditation Commission (TAC) of the Accreditation Board for Engineering and Technology (ABET) met July 23-27, 1997 to act on the accreditation evaluations that took place during the 1996-97 academic year. TAC actions are based on information provided in the institution's Self-Study Questionnaire, the findings of the on-campus visiting team, and the institution's written response to the team's draft statement of findings. This information is summarized in a report by the visiting team chair and debated by the full commission before an accreditation action is voted. The resulting evaluation for Ferris State University follows:*

Mechanical Engineering Technology, ad

Accredit this program to September 30, 2003 and visit. A request to ABET by January 31, 2002 is required for a reaccreditation visit.

This is a newly accredited program. Please note that the accreditation will extend to the graduates of the program of the previous year.

*** Note: The letters a,b,d, & e are used in the listing to identify the type of program accredited: a=Associate, b=Bachelors, d=day and e=evening program.**

(Continued)

111 Market Place, Suite 1050, Baltimore, MD 21202 • 410-347-7700 • Fax: 410-625-2238

Ferris State University

The policy of ABET is to grant accreditation for a limited number of years in all cases. The period of accreditation is not an indication of program quality. Any restriction of the period of accreditation is based on observed and reported conditions that could change within the specified period of accreditation. Continuation of accreditation beyond the time specified requires a re-evaluation of the program at the request of the institution, as noted in the accreditation action cited above.

Enclosed is the Final Visitation Report to your institution which discusses the findings on which the TAC's action was based. It is a revision of the draft report you previously reviewed, modified to reflect the TAC's consideration of your institution's recent response.

A list of accredited programs is published annually by ABET. Information for your institution will be listed in the forthcoming ABET Accreditation Yearbook. If a program cited above is incorrectly described, please notify ABET at once.

ABET policy prohibits disclosure of the period for which a program is accredited. For further guidance, please refer to the enclosed "Public Release Policy."

It is the obligation of the officer responsible for engineering technology programs at your institution to notify ABET of any significant changes in staffing, administration, curriculum content, or program title during the period of accreditation and to submit catalog revisions to ABET whenever such revisions are published.

Ferris State University

If you wish to make comments on an accreditation action, please advise ABET as soon as possible, and not more than 30 days after the date of this letter. Please note that appeals are allowed only in the case of 'not to accredit' or 'not to reaccredit' actions; all other actions result in program accreditation for the period specified. Also, appeals can only be based on the conditions stated in the first paragraph of the Appeals Policy and Procedure.

Sincerely,

Stanley I. Proctor

Stanley I. Proctor
President

SIP/es

Enclosures
    Final Statement
    Public Release Policy

cc: Joseph A. Glad, TAC Chair
    Alan C. Dixon, Team Chair
    W. David Baker, Editor
    Mark Curtis, Interim Dean
    Charles Matrosic, Assistant Dean

Accreditation Board for Engineering and Technology, Inc.

PUBLIC RELEASE POLICY*

Accreditation by the Engineering Accreditation Commission (EAC), Technology Accreditation Commission (TAC), or Related Accreditation Commission (RAC) of the Accreditation Board for Engineering and Technology (ABET) is based on satisfying minimum educational criteria. As a measure of quality, it assures that only an accredited program satisfies the minimum standards. The various periods or terms of accreditation do not represent a relative ranking of programs in terms of quality. At no point is an institution permitted to publish or imply the term or period of accreditation. The institution must assure that announcements or releases make no implication that accreditation by the EAC, TAC, or RAC of ABET applies to programs other than those accredited.

College catalogs and similar publications must clearly indicate the programs accredited by the EAC, TAC, or RAC of ABET as separate and distinct from any other programs or kinds of accreditation. No implication should be made in any listing that all programs are accredited because of an institution's regional or institutional accreditation. Accredited engineering programs should be specifically identified as "accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology." Accredited engineering technology programs should be specifically identified as "accredited by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology." Accredited engineering-related programs should be specifically identified as "accredited by the Related Accreditation Commission of the Accreditation Board for Engineering and Technology."

Direct quotations in whole or in part from any statement by the EAC, TAC, or RAC of ABET to the institution is unauthorized. Correspondence and reports between the accrediting agency and the institution are confidential documents and should be released only to authorized personnel at the institution. Any document so released must clearly state that it is confidential. Wherever institutional policy or State or federal laws require the release of a confidential document, the entire document must be released.

In the case of engineering programs accredited by the Engineering Accreditation Commission, the following also applies:

In addition to an accredited advanced-level program, an institution may offer one in the same discipline of study for which it does not seek accreditation that would allow the admission of nonengineering students and/or baccalaureate engineering degree holders from other programs of study who may not wish to satisfy all the basic-level requirements for entrance to the advanced-level accredited program. Such programs must be clearly differentiated as to title, content, objectives, and accreditation status.

Information published for students, prospective students, and the general public on an engineering program should provide sufficient definition of the program to show that it meets the ABET accreditation criteria. For example, if some fraction of the elective courses must be taken in one curricular area in order for the criteria to be met, this requirement should be published, even though adequate counseling of students by faculty members may be shown to achieve the same objective.

---

*See section II.D. in the EAC, TAC, or RAC criteria.

ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY

TECHNOLOGY ACCREDITATION COMMISSION

FINAL VISITATION REPORT

on

FERRIS STATE UNIVERSITY

Big Rapids, Michigan

Dates of Visit:	October 7-8, 1996
Team Chair:	Alan C. Dixon Broome Community College Binghamton, New York

Team Members

Name and Address	Program Visited Degree Granted
Steven C. Wells Old Dominion University Norfolk, VA	Mechanical Engineering Technology Day Program Associate in Applied Science
Swaminadham Midturi Texas A&M University College Station, TX	

APPENDIX B

EXPLANATION OF THE FINAL VISITATION REPORT

This report supports the accreditation action taken by the Technology Accreditation Commission (TAC) of the Accreditation Board for Engineering and Technology (ABET).

The Final Visitation Report is based on the Preliminary Visitation Report modified as necessary to correct any significant errors of fact or interpretation that may have been made. It is intended to be a comprehensive report of conditions observed at the time of the campus visit, and to reflect both the original visit findings and the evaluation of the institution's response.

In making its accreditation decision, the Technology Accreditation Commission took into consideration any corrective action taken by the institution after the visit and reported in the response to the Preliminary Visitation Report. According to the policy set forth in the Criteria for Accrediting Programs in Engineering Technology, weaknesses existing at the time of the visit are considered to have been fully corrected only when the corrective action has actually become effective. However, steps taken toward the correction of deficiencies have also been taken into account. The accreditation action taken represents the TAC's evaluation of the extent to which the program as a whole is in compliance with the overall Criteria for Accrediting Programs in Engineering Technology.

The Final Visitation Report may include requirements for corrective action, recommendations for improvement or correction, and suggestions for strengthening the programs under consideration.

A requirement results from an apparent failure of the program to meet a mandatory provision of the ABET Criteria for Accrediting Programs in Engineering Technology.

A recommendation relates to a weakness in complying fully with some provision of the criteria. Both requirements and recommendations require appropriate corrective action.

Suggestions are offered for consideration by the institution to strengthen a program or correct conditions which do not constitute violations of the criteria.

In order to clearly identify significant changes to the Preliminary Visitation Report, deletions are indicated by the following symbol: ###. Additions and major changes are indicated by double asterisks (**) at the beginning and end of the new section. Recipients may refer to the Preliminary Visitation Report for further identification of the changes, if desired.

FERRIS STATE UNIVERSITY

Big Rapids, Michigan

INSTITUTIONAL FACTORS AFFFECTING
THE ENGINEERING TECHNOLOGY UNIT

Introduction

Ferris State University is a comprehensive public four-year college located in the community of Big Rapids, Michigan, a city of approximately 12,600 residents. It is the county seat for Mecosta County located approximately midway between the northern and southern ends of Michigan's Lower Peninsula. This former logging community is in the heart of an extensive recreation area of which Mecosta County, with its 101 lakes and four county parks, is a significant part. The university's career-oriented mission dates to its origin in 1884, when Woodbridge N. Ferris, later a two-term Michigan governor and U.S. Senator, established a private industrial school in Big Rapids. The original intent was to retrain out-of-work lumberjacks, and the mission is still to provide students with marketable skills for a changing society. Michigan has a booming economy with nine out of ten graduates finding jobs directly related to their major field of study.

Ferris State University provides a career-oriented education to more than 10,000 students each year and awards degrees at the associates, bachelor's, masters and professional doctorate levels. There are seven colleges: Allied Health Sciences, Arts and Sciences, Business, Education, Optometry, Pharmacy, and Technology.

Institutional Strengths

1. The campus is a large, modern and well planned facility with a technology unit that houses 30 technical programs serving 2500 students. The college is appreciative of its students and works to make the college experience a positive one. Students spoke well of the college and it's faculty. There is an automated telephone registration system connected to the campus computer system. With this system students are able to register for courses from home by using the touch tone keypad.

2. There is an outstanding faculty, administration, and staff to support the technology unit. The Mechanical Engineering Technology program is held in high regard as a lead program at the institution. The university expressed a very strong commitment to technology.

3. Industry representatives and graduates are very complimentary of the program. The industry advisory committee is active and effective. Industry has an excellent history of donating modern and expensive equipment for the use of the technology unit.

4. The university has an excellent reputation in the community, and a strong market demand for technology graduates exists. Placement of graduates is a high priority at the institution. Surveys to determine graduate and employer satisfaction with the program are done periodically to assist in program improvement and curriculum design. Students are able to prepare quality resumes with the assistance of personnel from the Placement Services office. These resumes become part of a data base that is accessible by employers from a web page.

5. The computing facilities on campus are excellent. There are numerous laboratory areas along with faculty offices that are equipped with state of the art equipment. Students were found using the word processing software, CAD programs, and the Internet in excellent computing facilities.

6. The college library is an efficient facility with excellent evening and weekend hours. Library services are supported by an on line catalog, the ASTI guide, Eric, and other CD-ROM resources. Many periodicals are on microfiche including Ferris' selection as a site of resources for the US Patent Office.

Institutional Weaknesses

Note: These weaknesses are considered to be applicable to all of the programs evaluated, whether or not the weaknesses are specifically cited under each program evaluation.

1. There is not a satisfactory reviewing process for admitting students to the Mechanical Engineering Technology program. Students can begin the core curriculum without obtaining a minimum level of competency in mathematics. Students should not begin the program until they have completed the MAT 110 course. The program is rigorous and has a high attrition in the first year. Much of this is attributed to poor mathematics preparation before starting the program. Section V.G.3. of the ABET criteria requires that proper academic advising be provided to ensure that students are adequately prepared to meet the requirements of the program. It is required that the college establish guidelines in the area of mathematics for admission to the Mechanical Engineering Technology program. ****The institution has reviewed it's admission requirements and has implemented procedures to assure that each entering student will meet minimum mathematics entrance requirements.****

2. While the library is an excellent facility dedicated to the service of students, the specific holdings related to the Mechanical Engineering Technology program (LC TJ section) are outdated and inadequate to support a modern curriculum. Books in the Electrical Engineering Technology section (LC TK) represent an excellent example of current and appropriate materials. Section V.K.5. of the ABET criteria requires library holdings to include a sufficient number of books to support the program. It is required that a program be established to purchase a selection of modern books related to the Mechanical Engineering Technology program. The program faculty should be involved at a primary level in the selection of such texts. ****The library has ordered 94 new books in the subject area. In addition, 157 other texts have been collected from faculty to enhance holdings related to the Mechanical Engineering Technology program.****

Other Comments on Institutional Factors

1. A large percentage of Mechanical Engineering Technology students continue on to a baccalaureate degree program at Ferris State University and neglect to apply for the Mechanical Engineering Technology associates of applied science degree. More students should be encouraged to undergo this formality to both improve statistics on Mechanical Engineering Technology graduates and also afford graduates the security an associate degree provides in the event they do not complete the baccalaureate program of choice. ****The institution is implementing successful completion of the Associate of Applied Science degree as a necessity for admission to the Bachelor of Science degree programs.****

2. TAC of ABET asks that all institutions encourage faculty, adjunct faculty, and members of industry advisory committees to become program evaluators. There is a special need for evaluators form

industry as well as minorities and women. Interested persons should contact their technical society or ABET headquarters for more information.

PROGRAM EVALUATION

MECHANICAL ENGINEERING TECHNOLOGY

Associate Degree - Day Program

Introduction

The Mechanical Engineering Technology program has been in place since 1971 and is located in a 170,000 square foot facility called the Swan Technical Building. This center houses twelve degree options in a variety of fields including Electrical/Electronic Engineering Technology, Manufacturing Engineering Technology, and Plastics Engineering Technology. All programs are intended to serve the training needs of business and industry in western Michigan. This is an initial accreditation evaluation for the Mechanical Engineering Technology program.

This program was evaluated using the ABET *Criteria for Accrediting Programs in Engineering Technology* and the "Program Criteria for Mechanical Engineering Technology and Similarly Named Programs" dated November 4, 1995. The curriculum meets the minimum quantitative requirements for credit distribution in the subject areas prescribed by section V.A.1. of the ABET criteria. Strengths and weaknesses in meeting other provisions of the criteria are described below.

Program Strengths

1. The program is supported by exceptional computing facilities and equipment available to it. Most computer labs have Pentium class equipment with 17" monitors. All Personal Computer's have

both Windows and DOS environments, along with word-processing, spreadsheet, CAD, and communication software.

2. The ability to communicate ideas is essential for graduates of engineering technology programs. Students in the Mechanical Engineering Technology program were taped during oral communications demonstrating good use of oral reporting skills. Technical writing and the use of computers to create reports is an additional asset for graduates of technical programs. In this program, the MECH-221 course requires both oral communications and the use of computers to provide an integrated learning experience for students.

3. The students have a high regard for the program and Ferris State University as a whole. There is a great deal of respect for this well qualified and dedicated faculty. Students were anxious to share classroom experiences with the visiting team and were helpful in demonstrating available software on computers.

4. The laboratory facilities supporting the program are modern and well equipped. Equipment dollars are tight, but donations by local industries have significantly helped in maintaining program quality. There are a wide variety of laboratory experiments in use by students with this equipment.

Program Weaknesses

Note: The weaknesses cited under Institutional Factors are applicable to this program area as well.

1. Four of twelve courses use textbooks from 8 to 23 years old. (MECH 240 - 8 years old, MECH 212 - 23 years old, MECH 222 - 13 years old, EEET 215 - 11 years old). Section V.D. of the ABET criteria specifies that "technical currency is important and must be assured." The technical skills of students must be current and appropriate to the education of students in modern techniques of applied design. It is required that more recent titles be adopted to replace older texts. ****The program has adopted new texts for the four courses cited.****

2. The strength of a program depends heavily on the ongoing professional development activities of its faculty. Some Mechanical Engineering Technology faculty are not participating in professional development activities. Section V.F.9. of the ABET criteria requires that faculty remain current through the active participation in professional societies, continuing education, consulting, etc. It is recommended that a higher percentage of faculty participate in professional development activities. ****The institution has documented recent professional development activities for all faculty members and indicated that this will be a priority.****

3. The display of student work in one course was insufficient for team members to evaluate the effectiveness of this course (MECH 223). Section III.B.1.c.9. of the ABET criteria requires that sufficient examples of student work in technical courses be made available to team members. It is recommended that additional examples of student work be made available for the next evaluation visit.

****Students have begun keeping portfolios that will be duplicated and archived for the next TAC of ABET visit.****

4. While there is outstanding computing equipment available at the university, it was not evident that it was being used in a majority of the program's technical design courses. Section V.C.6. of the ABET criteria and section VI.N.2.b.4 of the ABET program criteria stresses the importance of the applications of computers in technical course work. It is recommended that more technical course work include applications of computers. ****Specific computing assignments have been added to four courses effective with the Spring 1997 semester.****

Other Comments on the Program

1. The kinematics course can be improved with the use of computer software such as Mechanimator, Interactive Physics, or Working Model Software. Students appreciate the opportunity to apply computing skills in this type of course. ****Excel spreadsheets have been introduced into the course. Other new software is being reviewed.****

2. The electrical course should include more work in programmable logic controller programming. The university has excellent donated equipment that makes this very possible. ****Inclusion of PLC's has been requested in the EEET 215 course.****

APPENDIX C

Mechanical Engineering Technology

APRC 1997-1998

Section 3 of 4

CRITERIA FOR ACCREDITING PROGRAMS IN ENGINEERING TECHNOLOGY

Effective for Evaluations During the
1996-97 Accreditation Cycle
(Incorporates all changes approved by the
ABET Board of Directors as of November 4, 1995)

Technology Accreditation Commission
Accreditation Board for
Engineering and Technology, Inc.
111 Market Place, Suite 1050
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CRITERIA FOR ACCREDITING PROGRAMS IN ENGINEERING TECHNOLOGY

Table of Contents

VI. Program Criteria (Continued)

Criteria for Accrediting Programs in Engineering Technology*

For Programs Evaluated During the 1996-97 Accreditation Cycle

I. INTRODUCTION

I.A. Purposes

The purposes of the Accreditation Board for Engineering and Technology (hereafter referred to as ABET) as related to accreditation are stated in the Constitution as follows:

I.A.1. Organize and carry out a comprehensive program of accreditation of pertinent curricula leading to degrees, and assist academic institutions in planning their educational programs.

I.A.2. Promote the intellectual development of those interested in engineering and engineering-related professions, and provide technical assistance to agencies having engineering-related regulatory authority applicable to accreditation.

I.B. Responsibilities

I.B.1. ABET accomplishes its purposes through standing committees or commissions, one of which is the Technology Accreditation Commission (hereafter referred to as TAC or TAC of ABET). The accreditation commissions are charged with the following responsibilities.

I.B.1.a. The accreditation commissions shall propose policies, procedures, and criteria to the ABET Board of Directors for approval. The Board of Directors shall review policies, procedures, and accreditation criteria and may specify changes to be made in them to the appropriate accreditation commissions.

I.B.1.b. The accreditation commissions shall administer the accreditation process based on policies, procedures, and criteria approved in advance by the Board of Directors. The accreditation commissions shall make final decisions, except for appeals, on accreditation actions.

I.B.2. Procedures and decisions on all appeals to accreditation actions shall be the responsibility of the Board of Directors.

I.C. Objectives of Accreditation

The purposes stated above are basic to accreditation efforts in engineering technology education. Accreditation seeks to attain the following specific objectives:

I.C.1. To serve the public, industry, and the engineering profession generally by stimulating the development of improved engineering technology education.

I.C.2. To identify for prospective students, student counselors, parents, potential employers, public bodies, and officials, engineering technology programs which meet the minimum ABET criteria in engineering technology.

I.C.3. To provide stimulation leading to curricular improvement in existing programs and to assist in the development of educational models for establishing new engineering technology programs as increased service to the public interest.

I.D. Development

ABET is recognized by the U.S. Department of Education as the sole agency responsible for accreditation of educational programs leading to associate and baccalaureate degrees in engineering technology. In 1944 the Engineers' Council for Professional Development (now ABET) appointed a Subcommittee on Technical Institutes. On October 5, 1964, this subcommittee became a standing committee of ECPD and established a basis for accrediting programs of the technical institute type, now designated as programs in engineering technology. Amendments and additions have from time to time been adopted. The original statement and its amendments and additions are combined here into a unified statement of the policies, methods of evaluation, criteria, and procedures which pertain to the accreditation of engineering technology programs.

I.E. Description of Programs

I.E.1. Programs to be considered are technological in nature and are in the field of higher education. Instruction is in the broad area of technical education between engineering and vocational education/industrial technology.

I.E.2. The definitions that follow clarify terms used by TAC of ABET.

I.E.2.a. Engineering technology is a part of the technological field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational spectrum between the craftsman and the engineer at the end of the spectrum closest to the engineer. The term "engineering technician" is applied to the graduates of associate degree programs. Graduates of baccalaureate programs are called "engineering technologists."

I.E.2.b. An engineering technology program is a planned sequence of college-level courses designed to prepare students to work in the field of engineering technology. The term "college-level" indicates the rigor and degree of achievement required.

I.E.3. Briefly, the differences between educational programs in engineering technology and industrial technology include type of faculty, use of facilities, mathematics and science sequence content, and degree of specialization. More faculty members with professional educational backgrounds appear to staff the present industrial technology programs, whereas a larger number with engineering or technological backgrounds staff the engineering technology programs.

***Incorporates all changes as of November 4, 1995**

II. POLICIES

II.A. Accreditation Policies

Accreditation of programs in engineering technology is accomplished under the following general policies.

II.A.1. TAC of ABET will consider for accreditation programs offered in an institution of higher learning in one of the following categories:

II.A.1.a. Institutions currently accredited by a regional or national institutional accrediting agency or formally approved by a State authority recognized by the U.S. Department of Education.

II.A.1.b. Institutions holding appropriate approval by a State authority to offer only engineering, engineering technology, or engineering-related programs, of a combination thereof, and not offering programs in any other field or discipline; or other institutions offering programs in engineering technology whose accreditation would further the objectives of ABET.

II.A.2. Programs are considered for accreditation action only at the written request of the institution.

II.A.3. Only individual programs are accredited, rather than institutions, for it is recognized that programs of different standards and objectives may be found at the same institution. When a multi-campus institution presents programs for accreditation, each campus will be considered as a separate institution in the evaluation process. In order for a program to be accredited, all options, concentrations, or other routes to completion of the program must be accreditable.

II.A.3.a. Options, Alternative curricula within a major engineering technology program (commonly called options) leading to a degree in a subfield of the major discipline may be accredited and listed as separate programs at the request of the institution. In such case the option must have been formally designated by the institution prior to the request for evaluation. It must conform to the criteria and to any program criteria applicable to independent programs in the same curricular area as the option. The accreditation status of the option must be clearly identified and distinguished from any non-accredited options within the same major program, and from any other programs.

II.A.3.b. Evening Programs — Evening programs will be accredited separately from regular day programs at the same institution unless the day and evening programs follow the same curriculum, use the same or equivalent laboratory equipment and facilities, are under the supervision and control of the full-time program faculty, and include equal rigor of student work and grading.

II.A.3.c. Off-campus Programs — Programs, day or evening, regularly offered at locations other than the principal campus will be accredited separately, unless the conditions of II.A.3.b. above are satisfied and a substantial portion of the off-campus courses are taught by the resident faculty of the principal campus.

II.A.4. As used in these criteria, the word must indicates definite obligatory requirements that TAC expects as a minimum to be met for a program to be accreditable by TAC of ABET. The word should indicates more permissive recommendations that may have an effect on accreditation.

II.A.5. Accreditation by TAC of ABET is based on meeting differential criteria applicable to programs which lead to the associate degree or to the baccalaureate degree.

II.A.6. An evaluation visit for accreditation will be carried out only if students have been graduated from the program prior to the on-site visit. If granted, such accreditation will extend to the graduates of the program of the previous year.

II.A.7. Qualitative factors, as well as quantitative factors, are given careful consideration through a visit by an evaluation team of competent personnel appropriately constituted for the curriculum under consideration.

II.A.8. Although rigid quantitative standards are not considered sacrosanct, programs are expected to meet the minimum standards delineated in the criteria. Well-planned experimentation and development in engineering technology education are encouraged. Experimental or nontraditional programs will be evaluated against the intent of the minimums established.

II.A.9. Such matters of broad institutional function as administration, student personnel services, library, arts and sciences, etc., are considered only with respect to services rendered to engineering technology and are reviewed with different emphasis within institutions with regional accreditation versus those without such accreditation. When an institution not holding regional accreditation is visited, these areas are examined in depth within ABET policy.

II.A.10. Accreditation is denied to programs which omit instruction in a significant portion of a subject in which technicians and/or technologists in a particular field may reasonably be expected to have competence. This policy is intended to be a safeguard to the public and should not entail the setting of rigid standards.

II.A.11. The institution presents complete data pertinent to a comprehensive evaluation. Information supplied by the institution is for the confidential use of ABET and will not be disclosed without the written authorization of the chief administrative officer of the institution or his/her designee.

II.A.12.

II.A.12.a. Caution and discretion must be exercised by institutions in all publications and references to avoid ambiguity or confusion among engineering technology, engineering and engineering-related specialties. TAC of ABET will not accredit a program in engineering technology if the institution makes the claim that the program is intended to give its graduates the equivalent of an engineering education as defined by ABET, or improperly uses the term "engineer" or "engineering" in any of its official publications. Where confusion exists, the institution must take positive steps in its publications and other media to help the public distinguish between engineering technology and engineering programs.

II.A.12.b. Although the selection of program titles is the prerogative of educational institutions, ABET discourages the proliferation of engineering technology program titles, because different titles for essentially the same program are confusing or misleading to the public, including students, prospective students, and employers. Preferred curriculum titles for accredited programs would include the words "engineering technology." No program will be approved for accreditation or reaccreditation unless the word "technology" is used as the final noun in the title.

II.A.12.c. For accreditation to be granted, a program must have a title that is consistent with the curriculum content, and the content must satisfy the ABET criteria and Participating Body program criteria applicable in accordance with section VI. as appropriate to that content.

II.A.13. A draft visitation report is submitted to the dean or appropriate academic administrator of the institution for comment on the factual elements of the report before accreditation action is taken.

II.A.14. The findings and recommendations of the visiting team are submitted for review by the appropriate officers of TAC of ABET and then by the full membership of the commission. The final decision on accreditation rests with TAC of ABET, except in cases of appeal of not-to-accredit actions, which are the responsibility of the ABET Board of Directors.

II.A.15. A list of currently accredited programs is published annually. The accredited status of a program listed in the ABET Accreditation Yearbook applies to all graduates who completed the program during the academic year indicated therein.

II.B. Revocation of Accreditation

Questions regarding the continued compliance of such programs during the period of accreditation may be directed to ABET. If it appears that an accredited program is not in compliance with ABET criteria, the institution is so notified. If the response from the institution is not adequate, ABET may institute revocation for cause procedures. The institution is notified of the reasons why revocation is to be instituted. An on-site visit is scheduled to determine the facts. A comprehensive document showing the reasons for revocation is provided to the institution for its analysis and its response. If the institution's response is not adequate, revocation for cause is implemented. The institution is promptly notified by the president of ABET of such action together with a supporting statement showing cause. A revocation constitutes a "not-to-accredit" action and is appealable. Accreditation is continued until the appeal procedure has terminated.

II.C. Appeal Policy and Procedure

II.C.1. In the event an institution wishes to appeal an action of "not-to accredit" taken by TAC of ABET, written notice of intent to appeal must be given to the Executive Director of ABET within 30 days of the date of notification of the action. Prior to format consideration of an appeal by the ABET Board of Directors, two alternate courses of action are available. The institution may request an immediate revisit in cases where the program will undergo substantive and documented improvement prior to the onset of the next accreditation cycle. In cases where an institution can demonstrate that there were major, documented errors of fact in the information that the commission utilized, the program may be a candidate for reconsideration.

II.C.2. Upon request of the institution, the TAC Executive Committee will consider either a revisit at the institution's expense, or reconsideration of the commission's action. In cases where a request for a revisit is approved, the institution is deemed to have waived its right to appeal either the original not-to accredit action or the action resulting from the revisit. In the event either kind of request is denied, the institution retains the right to pursue an appeal.

II.C.3. Upon receipt of an appeal notice, the president of ABET will appoint a special committee of the Board of Directors having a minimum of three members. This special committee will schedule a meeting at the ABET headquarters or other location as soon as practical and convenient for all parties concerned. Appropriate administrative officers of the institution and representatives of TAC of ABET will be present at this meeting to consider the importance and relevance of statements submitted in support of the appeal. The findings of the special committee will be reported to the next scheduled meeting of the Board of Directors, and final action will be taken.

II.D. Public Release Policy

II.D.1. Accreditation by TAC of ABET is based on satisfying minimum educational criteria. As a measure of quality, it assures only that an accredited program satisfies the minimum standards. The various periods or terms of accreditation do not represent a relative ranking of programs in terms of quality. At no point is an institution allowed to publish or imply the term or period of accreditation. Public announcement of the accreditation action should only relate to the attainment of accredited status. Because accreditation is specific to a program, all statements on accreditation status must refer only to those programs that are accredited. No implication should be made by an announcement or release that accreditation by TAC of ABET applies to any programs other than the accredited ones.

II.D.2. College catalogs and similar publications must clearly indicate the programs accredited by TAC of ABET as separate and distinct from any other programs or kinds of accreditation. No implication should be made in any listing that all programs are accredited because of an institution's regional or institutional accreditation. Accredited engineering technology programs should be specifically identified as "accredited by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology."

II.D.3. Direct quotation in whole or in part from any statement by TAC of ABET to the institution is unauthorized. Correspondence and reports between the accrediting agency and the institution are confidential documents and should only be released to authorized personnel at the institution. Any document so released must clearly state that it is confidential. Wherever institution policy or state or federal laws require the release of any confidential documents, the entire document must be released.

II.D.4. If accreditation is withdrawn or discontinued, the institution will no longer refer to the program as being accredited.

III. METHOD OF EVALUATION

III.A. Questionnaire

One of the first steps in the accreditation process for a program is the submission by the institution of information and data in the form of a self-study questionnaire and its review by TAC of ABET prior to an on-site visit.

III.B. On-site Visit

III.B.1. The questionnaire will be supplemented by a report of an on-site visit by a carefully selected team drawn from the official engineering technology list of program evaluators. The purpose of the on-site visit is three-fold.

III.B.1.a. The visiting team will assess factors that cannot be adequately described in the questionnaire. The intellectual atmosphere, the morale of the faculty and the students, the caliber of the staff and student body, and the character of the work performed are examples of intangible qualitative factors that are difficult to describe in a written statement.

III.B.1.b. The visiting team will help the institution assess its weak points as well as its strong points.

III.B.1.c. The team will examine in further detail material compiled by the institution relating to but not limited to the following:

III.B.1.c.1. Auspices, control, and organization of the institution and of the engineering technology division.

III.B.1.c.2. Educational programs offered and degrees conferred.

III.B.1.c.3. Maturity and stability of the institution and of the individual educational programs.

III.B.1.c.4. Basis of and requirements for admission of students.

III.B.1.c.5. Number of students enrolled:

III.B.1.c.5.A. in the technology college or division as a whole, and

III.B.1.c.5.B. in the individual educational programs.

III.B.1.c.6. Teaching staff, teaching loads, and faculty salaries.

III.B.1.c.7. Physical facilities, adequacy of the educational plant devoted to engineering technology education.

III.B.1.c.8. Finances, investments, expenditures, sources of income.

III.B.1.c.9. Curricular content of the program and items of student course work. In order to make a qualitative evaluation of a program, it is necessary that the institution exhibit teaching materials such as course outlines and textbooks for all courses required for graduation. Sufficient examples of student work in technical, mathematics, and science courses must be available to the visiting team for the entire campus visit. The examples should show a range of grades for assignments, including homework, quizzes, examinations, drawings, laboratory reports, projects, and samples of computer usage in technical courses. Examples must also be presented to demonstrate compliance with the requirement for student competence in written and oral communications as specified in section V.C.5.a.

III.B.1.c.10. Provisions for keeping the program current.

III.B.2. Additional evaluation activities by the on-site visiting team include the following.

III.B.2.a. The team will review records of the employment of graduates to evaluate placement and performance in terms of goals stated for each program.

III.B.2.b. The team's factual findings are presented orally to the institution's chief executive officer or designee and such faculty personnel as he or she wishes to assemble. The opportunity is presented at this time for the correction of factual errors in the team's observations.

III.C. Review

Following these activities, the report of the on-site visiting team and the institution's response are reviewed by TAC of ABET prior to taking final accreditation action.

IV. PROCEDURE

IV.A. Application and Preparation for Visit

IV.A.1. Consideration of engineering technology programs for accreditation is done at the invitation of the institution. TAC of ABET is prepared to examine associate and baccalaureate programs that appear likely to satisfy the respective criteria. Programs offered by institutions in the United States are eligible for review.

IV.A.2. An institution desiring the accreditation of any or all of its programs leading to degrees in engineering technology may communicate directly with ABET headquarters. This will activate established arrangements for TAC of ABET to secure advance information by questionnaire, and to conduct an evaluation by a team constituted for that particular visit.

IV.B. Visit and Report

IV.B.1. Each visiting team is selected, on the basis of the programs to be considered, from lists provided by the professional societies. The visiting team reports its preliminary findings and recommendations in writing to the officers of TAC of ABET for editing and transmission to the institution visited.

IV.B.2. Between the time of the visit and the annual meeting of TAC of ABET, the responsible administrative officer of the institution may submit to the commission any supplemental information which he or she believes may be useful to the commission in its consideration and appraisal of the visiting team's report. The institution may submit additional information to the team chair that must be received at least two weeks prior to the annual decision making meeting. Any material to be considered by the commission must be in writing to be valid in a subsequent appeal. The operating policy of TAC of ABET has been to base its accreditation actions on the status of the respective program at the time of the on-site visit. However, the commission has maintained a flexible attitude toward the addition or modification of discrete items, based on conditions altered after the team visit but prior to the commission's accreditation deliberations. Weaknesses existing at the time of the visit are considered to have been corrected only when the correction or revision has been made effective, is substantiated by official documents signed by the responsible administrative officers, or other evidence required by TAC of ABET is provided. Where action to correct a problem has been initiated but not completed to the satisfaction of TAC of ABET, or where only indications of good intent are given, the action will not be considered in current accreditation deliberations.

IV.C. Accreditation Action

IV.C.1. Final decision on accreditation rests with TAC of ABET, which acts on the recommendations made to it by the visiting team and on consideration of the institution's response to the preliminary report of findings or, in the case of actions based on progress reports, on the institution's report.

IV.C.2. Accreditation of a program is granted for a limited period, not to exceed six years, with reappraisal stipulated at the end of this period. The term of accreditation is subject to review for cause at any time during the period of accreditation. Accreditation is granted only when conditions are considered to meet minimum criteria.

IV.C.3. A "not-to-reaccredit" action under "show cause" is effective as of the beginning of the academic year closest to September 30 of the calendar year following the year of the "not-to-reaccredit" decision by an accreditation commission or by the Board of Directors in appeal cases. The notification to the institution shall indicate (a) that the termination supersedes the accredited status listing of the program in the current ABET Accreditation Yearbook and (b) that ABET expects the institution to formally notify students and faculty affected by the termination of the program's accredited status, not later than September 30 of the calendar year of the "not-to-reaccredit" action.

IV.C.4. When reaccreditation of a program has been denied by the TAC and not reversed by the ABET Board of Directors on appeal, or when a program is being discontinued by the educational institution within the period for which accreditation has been granted, ABET will include a note in its next annual listing of accredited programs indicating the expected date for discontinuation of the program or expiration of accreditation. Accreditation of a program in the process of being discontinued may be extended on a year-by-year basis subject to acceptance by the TAC of a satisfactory continuation report by the institution.

IV.C.5. A comprehensive evaluation of the total engineering technology activity under TAC of ABET purview at an institution, including all engineering technology programs and the related supporting offerings, will be conducted at intervals not exceeding six years. Interim accreditation of individual programs may be requested by an institution at a time other than the established comprehensive evaluation date. However, the period of this interim accreditation of individual programs will not normally extend beyond the next scheduled comprehensive evaluation and accreditation date. The institution will be required to submit a questionnaire which would address only the program or programs to be evaluated.

IV.C.6. If, for any reason, the future of an accredited program appears precarious, or if definite weaknesses exist which should be strengthened, accreditation may be denied or withdrawn, or may be granted for a shorter period, usually two or three years. Such precarious conditions include uncertainty as to financial status, uncertainty due to nature of administrative organization, need for additions to or improvements in staff or equipment, a new or changing program, undue dependence upon a single individual, etc.

IV.C.7. ABET is authorized by its constituent organizations to publish a list of accredited engineering technology programs for use as desired by those agencies which require such a list. The list of programs which have been accredited by TAC of ABET is revised annually.

IV.D. Changes During Periods of Accreditation

IV.D.1. It is the obligation of the administration officer responsible for the engineering technology program at the institution to notify ABET of any changes in content and/or title of curriculum during the period of accreditation and to submit catalog revisions of accredited programs to ABET when the catalog revisions are published.

IV.D.2. TAC of ABET must be kept informed of program terminations and other significant changes in programs, staff, facilities, organization, enrollment, and other pertinent factors in institutions where engineering technology programs currently are accredited. If an accredited program is terminated by an institution, accreditation by TAC of ABET is automatically terminated at the same time.

IV.D.3. TAC of ABET will re-examine an accredited program should a finding of possible need be made during the normal term. The purpose is to protect the public interest by ensuring that the institution observes common canons of professional conduct in its operations. Upon receipt of information showing a possible cause for complaint, TAC of ABET will institute procedures that include one or more of the following steps:

IV.D.3.a. Advise the chief executive officer of the institution of the complaint and request information on the matter.

IV.D.3.b. Develop understandings with institutional officials as to the situation, its problems, and alternatives for relief.

IV.D.3.c. Present the matter to the Executive Committee of TAC of ABET for procedural advice and direction.

IV.D.3.d. Develop a plan of operation for response by the institution concerned, with an objective of providing mutually acceptable and equitable processes.

IV.D.3.e. Submit the cases as resolved or as needing decision to the Executive Committee or to the full commission.

IV.D.3.f. If a complaint is considered serious enough to warrant revocation of accreditation, the provisions of paragraph II.B. under **POLICIES** will be invoked.

V. GENERAL ACADEMIC CRITERIA

V.A. Program Level and Course Requirements

Engineering technology programs may be accredited at the associate degree level or at the baccalaureate level. Differential criteria are specified as the minimum course requirements for each level. This section of the criteria relates to the program performance in producing graduates from programs meeting minimum course criteria.

V.A.1. Accreditable associate degree programs must be characterized by the following minimums in course requirements:

V.A.1.a. A minimum of 64 semester hour credits or 96 quarter hour credits for a two-year associate degree.

V.A.1.b. 32 semester hour or 48 quarter hour credits of technical courses including technical sciences, technical specialties, and technical electives.

V.A.1.c. 16 semester hour or 24 quarter hour credits of an appropriate combination of basic sciences and mathematics of the type, level, and subject coverage specified in these criteria and applicable program criteria. The basic sciences component must include at least 4 semester hour or 6 quarter hour credits in areas specified in section V.C.4.b. below. The mathematics component must include at least 8 semester hour or 12 quarter hour credits in areas specified in section V.C.4.c. below. The remainder of the requirement may be met by appropriate course work in either basic sciences or mathematics. Course work in computer programming may not be included in the category of basic sciences and mathematics in satisfying the minimum quantitative requirements.

V.A.1.d. 9 semester hour or 13 quarter hour credits consisting of social sciences and/or humanities and instruction in written and oral communications appropriate to the program, of which at least 6 semester hour or 9 quarter hour credits are the study of communications. Some study in social sciences and/or humanities must also be included in the total requirement.

V.A.1.e. The balance of the program should be designed to achieve an integrated and well-rounded engineering technology program. The additional time is available for the implementation of the educational objectives of the institution and/or individual as they relate to ensuring adequate educational preparation for the graduate to function as an engineering technician. This includes the ability to use the computer in solving technical problems. Additional course work in engineering technology or related areas will be needed to fulfill such an objective. The institution must address such needs and objectives in developing the program and its contents. A maximum of 4 semester hours or 6 quarter hours of cooperative education experience, to enhance the skills of the technician, may be included in this portion of the curriculum toward meeting the minimum number of credit hours specified in section V.A.1.a. above, provided it meets the requirements of section V.C.7. below.

V.A.2. Accreditable baccalaureate programs must be characterized by the following minimums in course requirements:

V.A.2.a. A minimum of 124 semester hour credits or 186 quarter hour credits for a baccalaureate degree.

V.A.2.b. 48 semester hour or 72 quarter hour credits of technological courses including technical sciences, technical specialties, and technical electives.

V.A.2.c. 24 semester hour or 36 quarter hour credits of an appropriate combination of basic sciences and mathematics of the type, level, and subject coverage specified in these criteria and applicable program criteria. The basic sciences component must include at least 8 semester hour or 12 quarter hour credits in areas specified in section V.C.4.b. below. The mathematics component must include at least 12 semester hour or 18 quarter hour credits in areas specified in section V.C.4.c. below. The remainder of the requirement may be met by appropriate course work in either basic sciences or mathematics. Course work in computer programming may not be included in the category of basic sciences and mathematics in satisfying the minimum quantitative requirements.

V.A.2.d. 24 semester hour or 36 quarter hour credits consisting of social sciences and/or humanities and instruction in writing and oral communications appropriate to the program, of which at least 9 semester hour or 13 quarter hour credits are the study of communications and at least 8 semester hour or 12 quarter hour credits are in social sciences and/or humanities. The remainder of the requirement may be met by appropriate course work in either area.

V.A.2.e. The balance of the program should be designed to achieve an integrated and well-rounded engineering technology program. The additional time is available for the implementation of the educational objectives of the institution and/or the individual as they relate to ensuring adequate educational preparation for the graduate to function as an engineering technologist. This includes the ability to use the computer in solving technical problems. Additional course work in engineering technology or related areas will be needed to fulfill such an objective. The institution must address such needs and objectives in developing the program and its contents. A maximum of 8 semester hours or 12 quarter hours of cooperative education experience, to enhance the professional development of the technologist, may be included in this portion of the curriculum toward meeting the minimum number of credit hours specified in section V.A.2.a. above, provided it meets the requirements of section V.C.7. below. However, no more than half of the maximum (4 semester or 6 quarter hours) co-op credit may be counted in the upper division (junior/senior year) of the program.

V.A.3. ABET encourages innovative or novel program arrangements. Non-traditional programs will be evaluated against the above criteria to ascertain that the programs satisfy the intent of the minimums established.

V.B. Program Content and Orientation

V.B.1. The program content should provide an integrated educational experience directed toward development of the ability to apply pertinent knowledge to the solution of practical problems in the graduate's engineering technology specialty.

V.B.2. ABET requires a high degree of specialization for engineering technology programs, but with field orientation rather than task orientation. The engineering orientation of the technical specialization should be manifested by faculty qualifications and course content.

V.B.3. **Programs must have** written goals which are consistent with overall institutional goals. These goals **must**, as a minimum, focus on the student body served, resource allocation, and other factors directly affecting the program. Articulation of goals should be accomplished through specification of objectives by which achievement toward the goals can be measured. **Programs must** demonstrate achievements through various methods, e.g., student outcome assessments and employer feedback. **Programs must have plans for continuous improvement.**

V.C. Curriculum Elements

The quantitative criteria listed in V.A.1. and 2. above are now discussed as providing a minimum foundation for the preparation of an engineering technician or engineering technologist.

V.C.1. Technical Sciences—Subject matter in an engineering technology program has its roots in mathematics and basic science and carries knowledge further toward application. Courses are designated to supply the core of technological knowledge students need in their chosen profession. The same subject areas are included, with more emphasis on application than the "engineering science" of an engineering program.

V.C.2. Technical Specialties

V.C.2.a. Technical Skills and Techniques —These are courses in which the student would acquire the necessary skills and knowledge of appropriate methods, procedures, and techniques, such as graphics, problem solving, processes, construction techniques, instrumentation techniques, production methods, field operations, plant operations, safety, and maintenance. Technology laboratory manuals, experiments, projects, and activities should clearly reflect the orientation of the program toward the education of the student in the modem techniques of applied design, construction, operation, maintenance, testing, and some production processes. Among courses requiring laboratory work, sufficient written documentation of that work (such as formal reports, technical briefs, and engineering logbooks) is required to ensure that students become competent in communications. The documentation should be graded with respect to both technical content and writing skills.

V.C.2.b. Technical Design Courses— These are courses in practice-oriented standard design applied to work in the field, such as construction, in which students acquire experience in carrying out established design procedures in their own areas of specialization. The key to this type of technical design lies in the fact that the courses would follow established design concepts developed by engineering and that there would be prime emphasis on standard design procedures and practices. Many of these design methods have already been included in handbooks or standard computer methods for various branches of engineering. These courses would require an understanding of the application of mathematics and science, for example, to such activities as air conditioning systems design, duct design, piping design, amplifier design, computer component and circuit design, plant layout, materials handling operations, and/or civil engineering technology applications such as road design.

V.C.3. Technical Electives —Technical electives include any related technical courses which support the student's career interest (e.g., electronic circuits for a student in mechanical engineering technology).

V.C.4. Basic Sciences and Mathematics

V.C.4.a. Allocations within this group between basic sciences and mathematics will depend partly upon the specific program needs. For example, electronics might require a higher fraction of the total in mathematics than environmental engineering technology, which may have a greater basic sciences requirement. Courses in computer programming may not be included in the category of basic sciences and mathematics in satisfying the minimum quantitative requirements.

V.C.4.b. Basic Sciences —In a study of science, the objective is to acquire fundamental knowledge about nature and its phenomena. Toward this end, the courses should emphasize the understanding, measurement, and quantitative expression of the phenomena of nature. Laboratory work, including experimentation, observation, and accurate measurement, is a required part of the study of physical science. The basic sciences component of an engineering technology program may include physics, chemistry, and the life and earth sciences in accordance with specific program needs.

V.C.4.c. Mathematics

V.C.4.c.1. College algebra is the normal beginning point for the study of mathematics in engineering technology programs, and is the basis for the specified minimum mathematics credit and competence requirements. (See sections V.A.1.c. and V.A.2.c. above.) Program requirements should include carefully selected topics, suited to the individual program, from algebra through trigonometry to higher levels of mathematics. Competence in the application of algebra and trigonometry to problem solving must be demonstrated in appropriate technical courses.

V.C.4.c.2. In baccalaureate programs, particularly, the study of the concepts of calculus must be included in the program to ensure that students are professionally literate. Upper-level technical courses must include applications of calculus in technical problem solving where appropriate in the curriculum.

V.C.4.c.3. Study of the concepts of calculus must also be included in associate degree programs unless alternative subjects in mathematics beyond algebra and trigonometry are specified in the appropriate specific program criteria as developed by the professional societies and approved by ABET. (See section VI. below.)

V.C.5. Communications, Humanities, and Social Sciences

V.C.5.a. Communications— Good oral and written communications are considered by ABET to be a necessary achievement of a college graduate. Technically trained individuals should not be considered educated regardless of the depth of their technical capability if they cannot communicate, both orally and in writing, their technical findings, thoughts, and philosophy to others around them. Since it is by practice that the real importance of a specific aspect of educational endeavor is demonstrated to the student, a good technical educator will insist that reports be neat, grammatically correct, and lucid. It must be evident to the visiting team that graduates are proficient in the use of the English language and have developed the ability to communicate ideas and understand those of others. Course work in English composition, including both written and oral presentation, literature, and especially technical writing, is appropriate for meeting the quantitative requirement. Moreover, the visiting team will be looking for evidence that both oral and written communications have been taken into account in the review and evaluation of student technical work.

V.C.5.b. Social Sciences/Humanities—It is important that the student acquire an appreciation and understanding of our rich cultural heritage, the complexities of interpersonal relationships, and understanding of the interrelationship between technology and society, and a system of values essential for intelligent and discerning judgments. There will be variation in the specific courses offered in this general area from institution to institution. This by no means minimizes the importance of these courses to broaden the student in the general education area. Skill courses such as physical education or military drill do not qualify as social-humanistic studies.

V.C.6. Computer Competency — Engineering technicians and technologists are dependent upon the computer to effectively perform their job functions. It is therefore essential that students acquire a working knowledge of computer usage. Instruction in applications of software for solving technical problems and student practice within appropriate technical courses is required for all programs. Additionally in Baccalaureate degree programs, instruction must be included in one or more of the computer languages commonly used in the practice of engineering technology. Following formal instruction or demonstrated proficiency in computing skills, baccalaureate students should gain experience using programming skills in technical courses to an extent appropriate for the discipline.

V.C.7. Cooperative Education Experience—TAC of ABET does not separately identify cooperative programs. However, flexibility in the development of appropriate work experiences, such as a formal cooperative program, as part of an engineering technology program is encouraged. Work experience components will be evaluated as part of the evaluation of an entire engineering technology program, but credit for work experience may not be counted toward the minimum credit hour requirements in the categories prescribed in sections V.A.1.b. through d. or V.A.2.b. through d. Cooperative course credit may be included in the balance of the program as specified in sections V.A.1.e. and V.A.2.e. Where cooperative education experience is counted toward meeting the minimum total number of credit hours specified in V.A.1.a. or V.A.2.a. above, the cooperative education experience must include an appropriate academic component such as a seminar or written formal report addressing the experience and the educational benefits derived therefrom. This academic component must be graded by the faculty of the department responsible for the program's technical content. Material relating to the academic component must be provided for the visiting team's review. (See section III.B.1.c.9.)

V.C.8. Remedial Work— Remedial courses, designed to remove deficiencies in the background of entering students, are inherently at a level lower than expected in college credit work. Such courses, particularly in the areas of mathematics and communications, are not to be used to meet the minimums in curricular content requirements.

V.D. Technical Currency

In engineering technology programs, technical currency is important and must be assured by such means as a competent and inquisitive faculty, an active industrial advisory committee, an adequately funded budget which encourages continuing faculty development, and a modern library collection with an adequately funded program for continuous renewal. Positive procedures must be established and closely monitored to safeguard against technical obsolescence. These procedures should be described in the self-study questionnaire and demonstrated to the evaluation team during the visit.

V.E. Arrangement of Baccalaureate Programs

V.E.1. Some baccalaureate engineering technology programs have been developed using a single continuous four-year curriculum structure; others are organized on a "two plus two" or a "three plus one" plan wherein upper level studies are added to associate-degree-level work to form a baccalaureate degree program. The latter arrangement provides a specific associate degree exit with a concomitant job opportunity and also allows students the possibility of continuing their education toward a baccalaureate degree. The post-associate degree portions of the baccalaureate programs, hereafter referred to as upper-division-programs, vary considerably depending upon objectives. Some focus on continuation of the associate degree technical specialty whereas others are deliberately broader and may be considered interdisciplinary engineering technology programs. Considering the variety of legitimate local circumstances that may apply, these plans as well as others are acceptable if the total baccalaureate program reflects adequate work beginning at the freshman level and extending through the senior-level courses.

V.E.2. Upper-division programs generally accept students from TAC of ABET accredited associate degree programs. Students from nonaccredited associate degree programs should have appropriate validation of their work. It is expected that those students with deficiencies in their background preparation for the upper-division programs will be required to remove those deficiencies. In all cases, the accreditation process is intended to ensure that the graduate has achieved a level of competence expected in a baccalaureate program. Equivalence of courses and equivalence of credit hours must be determined by the receiving institution.

V.E.3. For those upper-division programs that continue the technical specialty, the courses should be structured on a "building block" basis, i.e., the advanced courses in the technical specialty should have as prerequisites the technical courses including mathematics from the associate degree program. These courses should obviously demonstrate a greater degree of sophistication and theory than those in the associate degree program.

V.E.4. For the "interdisciplinary" upper-division program, the technical courses must be designed with the student's academic background in mind. That is, it would be expected that a technical course at the junior level would cover more material and utilize greater mathematics content than a similar course at the freshman level in a specialty area. The "interdisciplinary" program must be clearly identified with an appropriate title.

V.E.5. Under no circumstances should an upper-division program that is predominantly management oriented be considered an engineering technology program, nor should two associate degree programs back-to-back be considered for baccalaureate accreditation.

V.F. Faculty

This section of the criteria relates to the technical faculty members' adequacy in credentials, numbers, and competence. The technical faculty, which may be the single most important factor in an educational program, will be evaluated individually and as a whole. Strong programs will have technical faculty members whose qualifications exceed what is described here as "basic credentials."

APPENDIX C

Engineering Technology Criteria-General

V.F.1. Each program must have appropriately qualified technical faculty members. Basic credentials are prescribed to assure the program is appropriately quantitative in nature and includes proper engineering and industrial emphases. A technical faculty member who has the following qualifications is viewed as having basic credentials with regard to technical competence, degree level, and industrial experience. Basic credentials consist of three years of relevant industrial experience and one of the following:

V.F.1.a. A master's degree in engineering or engineering technology, which is considered as the appropriate terminal degree.

V.F.1.b. A master's degree in a closely related field if the degree is primarily analytical and the subject clearly appropriate, e.g., a degree in physics for certain areas of electronics.

V.F.1.c. Professional registration and a master's degree.

V.F.1.d. For associate degree programs only, professional registration.

V.F.2. In exceptional cases there may be technical faculty members who satisfy the intent of the above minimums without literally satisfying the criteria. TAC of ABET may recognize these exceptions for a small fraction of the total engineering technology faculty if the institution convincingly demonstrates the equivalence.

V.F.3. Technical faculty members not satisfying paragraph 1 must have at least a bachelor's degree in an appropriate science or engineering-related field. Faculty members teaching the technical skills courses are not required to have advanced degrees but are expected to be artisans or masters of their crafts. However, they should represent only a small fraction of the total engineering technology faculty.

V.F.4. The number of faculty members needed in a program depends on the number of students in the program, the portion of students in evening or co-op programs, other duties assigned to the technical faculty and the teaching support the program receives from related programs. The number of faculty members must be great enough to provide a breadth of perspective, program continuity and proper frequency of course offerings. In establishing the Full-Time Equivalents (FTE) listed below, faculty members whose primary commitment is to a program count fully for that program unless the institution chooses to divide their time between programs. No single faculty member can total more than one FTE, even if an overload is carried for extra compensation.

V.F.4.a. Each associate degree program must have at least one faculty member with basic credentials whose primary commitment is to the program and a total of at least two FTE faculty members.

V.F.4.b. Each baccalaureate degree program must have at least two faculty members with basic credentials whose primary commitment is to the program and total of at least three FTE faculty members.

V.F.4.c. Each upper-division only baccalaureate degree program must have at least one faculty member with basic credentials whose primary commitment is to the program and a total of at least two FTE faculty members.

V.F.4.d. Closely related programs often share faculty members, facilities, and courses which enable them to satisfy the intent of paragraphs a. through c. with fewer faculty. Programs may be recognized as closely related if they share administrative and support services and if at least 50 percent of the technical courses are common. Each dependent closely related program must have at least one additional faculty member with basic credentials whose primary commitment is to the program.

V.F.4.e. If an institution convincingly demonstrates that breadth of perspective, program continuity, and proper frequency of course offerings are provided by alternate means, exceptions to items a. through c. may be considered.

V.F.5. Not only does a technical faculty require minimum numbers to adequately carry out its task, the group also must have balance, variety, and overall strength. For an associate degree program at least one-half of the FTE faculty must have basic credentials. For a baccalaureate degree program at least two-thirds of the FTE faculty must have basic credentials.

V.F.6. Engineering technology education emphasizes problem solving, laboratories, and technical skills. A sufficient number of faculty members are required to give adequate attention to each student in this environment. The student-faculty ratio depends on the nature of the program and courses, but should not exceed the institutional ratio in science-related areas. Student-faculty ratios for non-technical studies should follow normal institutional patterns.

V.F.7. Each accredited program must have a full-time faculty member assigned as department head, program coordinator, or similar term designating leadership responsibility. This faculty member should have basic credentials.

V.F.8. The overall competence and effectiveness of faculty members may be judged by such factors as the level of academic achievement; the diversity of their backgrounds; the extent to which they further their own education in relevant areas; industrial experience; teaching experience; being technically current; interest in and enthusiasm for improving instruction; involvement in laboratory development; publication and other scholarly activities; active participation in professional and scientific societies; favorable evaluations from students, graduates, and peers; the ability to communicate effectively in English; exemplary ethical and professional behavior; and involvement with students in extracurricular activities. A master's degree is viewed as the appropriate terminal degree.

V.F.9. The field of technology is changing rapidly. Thus, the currency of material being taught and the people teaching the material are of paramount concern to TAC of ABET. Faculty members must maintain current knowledge of their field and understanding of the tasks industry expects technicians and technologists to perform. Faculty members normally remain current by active participation in professional societies; reading the literature; continuing education; applied research; consulting and periodic return to industry. The institution should have a well-planned, adequately funded, and effective program for the professional development of its faculty.

V.F.10. Many factors may prevent an institution with accredited programs from changing its faculty composition to satisfy the requirements which were initially implemented in 1990-91. Programs continuously accredited since 1989-90 with employment constraints that prevent present full compliance with section V.F. of the ABET criteria, may be accreditable if it is demonstrated that present engineering technology faculty members are technically current and that faculty members hired since 1990-91 hold the basic credentials specified in section V.F.1.

V.G. Student Body

This section of the criteria relates to the admission of students, school policy on scholastic work, and the adequacy of operations for student advising, selective retention, and application of graduation requirements.

V.G.1. Entrance requirements should include high school graduation or the equivalent.

V.G.2. Institutional policies and procedures on credit for scholastic work (including transfer credit), retention, probation, and graduation must ensure that all graduates of a program accredited by TAC of ABET meet these criteria in addition to satisfying all program and institutional requirements.

V.G.3. Proper academic advising must be provided to ensure that students are adequately prepared to meet the requirements of the program.

V.G.4. The institution must maintain up-to-date admissions and academic records for all students and graduates.

V.G.5. Adequate placement services must be available to assist graduates in seeking employment.

V.H. Administration

The administration should demonstrate effective leadership and satisfactory support for engineering technology. The following factors relate to this provision.

V.H.1. A capable faculty can perform its functions best in an atmosphere of good relations with the administration. This requires good communication between faculty members and administrators, and a mutual concern with policies that affect the faculty.

V.H.2. The college administration should have four basic roles: selection, supervision, and support of the faculty; selection and supervision of the students; operation of the facilities for the benefit of the faculty and students; and interpretation of the college to members of the profession and to the public.

V.H.3. In performing many of these functions, the administrators should not operate alone, but should seek advice from individual faculty members, faculty committees, and special consultants.

V.H.4. Each program in engineering technology must have an identifiable, qualified person who has direct responsibility for program coordination and curriculum development. Such a person must be a full-time employee of the institution as specified in section V.F.7.

V.I. Satisfactory Employment

One of the distinguishing features of engineering technology programs is the desire to provide their graduates with enough acumen that there will be a minimum training period required in industry. An accreditable program must demonstrate employer satisfaction with recent graduates, graduate satisfaction with employment, career mobility opportunities, appropriate starting salaries, and appropriate job titles. Evidence of the above must be made available to the evaluation team during the visit.

V.J. Industrial Advisory Committee

V.J.1. Each accredited program must have an industrial advisory committee composed of industrial representatives, which must meet at least annually. Records and minutes of this committee should be maintained and be made available to the accreditation evaluation team. Industrial advisory committees can contribute significantly to the growth and development of engineering technology programs as a means of assuring technical currency of the program and maintaining close liaison with the supporting and employing industries.

V.J.1.a. An effective industrial advisory committee should:

V.J.1.a.1. Be broad-based and composed primarily of practicing engineers and senior engineering technicians with active interests in the institution and the program it offers and with intimate knowledge of the current work of engineering technicians and the work they are likely to do in the near future.

V.J.1.a.2. Meet regularly with the administration and the faculty to discuss program needs, progress, and problems, and to recommend solutions.

V.J.1.a.3. Periodically review program offerings and course content to ensure that the current and future needs of engineering technicians in industry are being met.

V.J.1.b. Industrial advisory committees should also be encouraged to:

V.J.1.b.1. Assist in the recruitment of a competent faculty and of potentially capable students.

V.J.1.b.2. Assist in the placement of graduates.

V.J.1.b.3. Assist in obtaining financial aid and part-time employment for needy students.

V.J.1.b.4. Assist in obtaining financial and material resources for the institution and in assuring a high level of community awareness and support of the program offerings.

V.J.2. To be effective, advisory committees must be properly supported, logistically and administratively. They should be given meaningful assignments that are properly within their areas of expertise, and their advice must be given serious consideration. Whenever their advice cannot be taken, such decision must be supported by good reasons.

V.K. Financial Support and Facilities

The institution must demonstrate that adequate facilities and financial support for each program are available. The following factors delineate the nature and degree of the support required.

APPENDIX C

Engineering Technology Criteria-General

V.K.1. ABET is concerned that financial and facility provisions are adequate as predictors of continuing quality in education and evidence of program stability. Faculty salaries sufficient to attract desirable candidates for open positions and to provide a reasonably stable staff at the institution and within technology departments are a major factor.

V.K.2. Adequate facilities in classrooms and laboratories are central to effective achievement of educational goals. Provisions for updating equipment in response to changing practices in technology is important. The availability of sufficient expendable materials to give students proper learning experiences is another essential to achieving goals. Laboratory manuals, experiments, and projects should clearly indicate that the facilities are being used to educate the student in modern techniques of applied design, construction, operation, maintenance, testing, production processes, etc.

V.K.3. It is particularly important that instruction in engineering technology be conducted in an atmosphere of realism. Theory courses should stress problem identification and solution, with emphasis on the quantitative, analytical approach, including the making of "order of magnitude" estimates quickly. They should be accompanied by coordinated laboratory experiences, including measurement, collection, analysis, interpretation, and presentation of data.

V.K.4. Laboratory equipment and computers should be of the type that would be encountered in industry and practice. Since one of the objectives of engineering technology programs is the development of technical skills, all students should be thoroughly familiar with the use and operation of analytical or measurement equipment common to their major field of study. Experience in the operation of standard or basic shop equipment such as lathes, welders, and engines does not, in itself, meet this requirement.

V.K.5. Equipment catalogs, professional magazines, journals, and manuals of industrial processes and practices should be readily accessible and used by technology students in addition to the usual library resources. Students should be familiar with the literature of their technology and encouraged to use it as a principal means of staying abreast of the state of the art in their technological field. Library usage is one indication of faculty interest in developing student skills in locating and utilizing information. Library holdings must include a sufficient number of appropriate books, periodicals, reference books and indexes, and standards documents to support the engineering technology programs. Library holdings may be in paper, microform, or electronic formats. Resources owned by the institution and physically present in the library may be supplemented by other resources, such as electronic information databases and full-text document delivery systems, which are not physically present in the library but which have been licensed for access via online networks.

V.K.6. Satisfactory secretarial/clerical support must be provided for the engineering technology faculty and administration.

V.K.7. Satisfactory procedures and/or qualified support personnel for repair and maintenance of laboratory and other instructional equipment and for general laboratory assistance must be provided.

VI. Program Criteria

Program criteria relative to the accreditation of engineering technology programs in particular disciplines are developed by the cognizant Participating Bodies of ABET or, at the request of TAC of ABET, by other societies or groups having appropriate expertise. The program criteria provide the specificity needed for interpretation of the general criteria as applicable to a given discipline. Program criteria must be accepted by the TAC and by ABET before they can have effect in the accreditation process. When approved, program criteria are published in this section as an integral part of this document. A program in a curricular area covered by approved program criteria must be in compliance with both the general criteria and the program criteria in order to be accredited. Provisions of the program criteria may be more restrictive than related provisions of the general criteria. Engineering technology programs in areas not covered by program criteria must meet the general criteria.

Program criteria amplify or interpret specific sections of the general criteria for programs in particular engineering technology disciplines. **The participating bodies of ABET will review and recommend updating of their respective Program Criteria at least every six years. If not revised/reviewed, that Program Criteria will be deleted.**

The program criteria which follow have been developed by the appropriate Participating Bodies of ABET, reviewed by the Technology Accreditation Commission (TAC), and approved by the Board of Directors of ABET. Before being adopted for implementation in the accreditation process they were published for review and comment. They will be applied by the TAC for accreditation actions during the 1995-96 academic year and following years.

Participating Bodies of ABET having responsibility for assigned curricular areas periodically propose non-substantive or editorial changes to the program criteria. Upon approval by the ABET Board of Directors, such changes will be published and placed in effect without advance publication for comment.

VI.A. PROGRAM CRITERIA FOR AIR CONDITIONING ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by the American Society of Heating, Refrigerating and Air-Conditioning Engineers
(Reviewed 1995)

1. Applicability.

These program criteria apply to air conditioning engineering technology programs, and those with similar modifiers in their titles, leading to either an associate or a bachelor's degree.

2. Curriculum.

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

Technical sciences must include topics in thermodynamics, psychrometrics, heat transfer, and fluid mechanics.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

There should be a core of courses in air conditioning engineering technology covering skills and techniques in air conditioning processes, heating/cooling load calculations, ventilation principles, pipe and duct design, system controls, system components, refrigeration, economic analysis, and computerized energy evaluation methods. Skills should be developed through laboratory experience.

Upper-division course work must complement and expand on lower-division work. The last year of the baccalaureate program should include a project or capstone course to integrate the knowledge learned in the technical specialties.

c. **Communications.** (Amplifies criteria section V.C.5.a.)

It must be demonstrated that the program's graduates are adequately prepared in both oral and written communications.

VI.B. PROGRAM CRITERIA FOR ARCHITECTURAL ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by The American Society Of Civil Engineers
(Reviewed 1995)

1. Applicability.

These program criteria apply to architectural engineering technology programs or closely related modifiers in their title, leading to either an associate's degree or a bachelor's degree.

2. Curriculum.

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

(1) Associate degree curricula must include topics in statics and strength of materials.

(2) Baccalaureate degree curricula must include topics in statics and strength of materials.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Associate degree curricula must include topics in architectural design, architectural graphics, architectural detailing, computer-aided drafting, contracts and specifications, construction materials and methods, building electrical/mechanical systems, elementary structures, materials testing, and estimating.

(2) Baccalaureate degree curricula must include topics in architectural design; architectural graphics; architectural detailing; computer-aided drafting; contracts and specifications; construction materials and methods; building electrical/mechanical systems, elementary structures; materials testing; estimating; architectural theory; building environmental control systems; building codes; concrete, steel, and wood structures design; planning and scheduling; and site planning.

c. **Mathematics.** (Amplifies criteria section V.C.4.c.)

(1)Associate degree programs in architectural engineering technology must ensure that a student understands and is able to use algebra, trigonometry, and analytic geometry.

(2) Baccalaureate degree programs in architectural engineering technology must ensure that a student understands and is able to use algebra, trigonometry, analytical geometry, and applied differential and integral calculus. The topics covered in mathematics must be used in the technical courses.

VI.C. PROGRAM CRITERIA FOR AUTOMOTIVE ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by the Society of Automotive Engineers
(Reviewed 1995)

1. <u>Applicability.</u>

These program criteria apply to automotive engineering technology programs and those with similar modifiers in their titles, leading to either an associate or bachelor's degree. The term "automotive" refers primarily only to ground vehicles and equipment intended for the movement of goods and people.

2. <u>Curriculum.</u>

a. **Technical Sciences** (Amplifies criteria section V.C.1.)

(1) Technical science courses must provide the science foundation for the technical specialties and be applications-oriented with a majority having an integrated or accompanying laboratory with emphasis on measurement, data collection, analysis, and documentation with written and/or oral report presentation.

(2) Technical sciences must include topics in the following for the associate degree: statics and basic mechanics of materials. For the bachelor's degree, in addition to the above, technical sciences must include course work in basic electrical science and should include topics covering the applications of: dynamics, advanced mechanics of materials (including testing), fluid mechanics (including hydraulics), heat transfer, thermodynamics, manufacturing processes, and electronic controls.

b. **Technical Specialties** (Amplifies criteria section V.C.2.)

(1) It is important for technical specialty courses to provide a general understanding of the vehicle as a total system which includes performance and handling needed to achieve its mission and a general exposure to the design, manufacture, and maintenance of the major subsystems and technologies normally found in automotive vehicles. These technologies include: power train (engine and driveline), brakes, fuels and lubricants and their emissions, suspension and steering, body and frame structure, body design, climate control, automotive electronics, and vehicle instrumentation. Associate degree curricular may incorporate an option oriented toward automotive maintenance, or the option to enable the graduate to assist engineers in the application of designs and in the development of automotive products. Any option selected must include the necessary fundamentals to enable graduates to matriculate to appropriate bachelor's degree programs.

(2) Technical design courses must stress the use of manuals, handbooks, and current commercial catalogues. Students should be provided with general knowledge and hands-on experience in relevant computer-aided design and computer-aided engineering applications.

(3) Technical courses should utilize the applications of probability and statistics and numerical methods.

c. **Basic Sciences and Mathematics.** (Amplifies criteria sections V.C.4.a. and V.C.4.b.)

(1) Basic sciences must include at least one course in physics which includes laboratory experience, and a chemistry course is also recommended.

(2) The bachelor's degree program must include applied differential and integral calculus.

3. <u>Industrial Advisory Committee</u> (Amplifies criteria section V.J.)

Responsive industry representatives with intimate knowledge of the full spectrum of the technologies, activities, and employment in the automotive industry within the institution's regional area should be encouraged to participate in the activities of the industrial advisory committee.

VI.D. PROGRAM CRITERIA FOR BIOENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by The Institute of Electrical and Electronics Engineers, Inc. (Lead society in cooperation with the American Institute of Chemical Engineers, American Society of Agricultural Engineers, American Society of Mechanical Engineers, and the National Institute of Ceramic Engineers)
(Reviewed 1995)

1. <u>Applicability.</u>

These program criteria apply to engineering technology programs including "biomedical," "medical electronics," "biomedical equipment," and similar modifiers in their titles, leading to either an associate or a bachelor's degree.

2. <u>Curriculum.</u>

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

Technical science courses must be applications-oriented with a majority having an accompanying laboratory with emphasis on measurement, data collection and analysis, documentation, and written/oral report preparation/presentation. Course work must include the fundamentals of electricity/electronics and principles of circuit analysis.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Technical skills and techniques courses must include, as appropriate to the program emphasis, instruction in electrical/electronic devices, digital fundamentals, linear integrated circuits, microprocessors, anatomy, physiology, and biomedical instrumentation. Courses at the associate degree level must prepare the student for immediate employment but must include sufficient foundation to enable the student to continue in upper-division studies without penalty. Upper-division course work must complement and expand lower-division work. All upper-division programs must include at least one 3-semester credit course in hospital internship.

(2) Technical design courses must stress the use of manuals, handbooks, and material/equipment specifications, and computers where applicable.

c. **Basic Sciences and Mathematics.** (Amplifies criteria section V.C.4.)

(1) The basic sciences must include physics and chemistry (with laboratory) presented in a rigorous algebra/trigonometry environment (as a minimum).

(2) A minimum coverage in mathematics is college-level algebra, trigonometry, and an introduction to calculus. Baccalaureate programs must include differential/integral calculus, and instruction in applied differential equations is strongly encouraged. Linear programming, numerical methods, and probability/statistics are other appropriate electives.

VI.E. PROGRAM CRITERIA FOR CHEMICAL ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by the American Institute of Chemical Engineers
(Reviewed 1995)

1. <u>Applicability.</u>

These program criteria apply to chemical engineering technology programs, and those with similar modifiers in their titles, leading to an associate degree.

2. <u>Curriculum.</u>

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

The curriculum must include courses in chemistry including but not limited to inorganic, organic, and analytical chemistry. All chemistry courses must include laboratory exercises. Chemistry courses may be counted as technical sciences or as basic sciences. Thermodynamics, process control and instrumentation, computer science, and materials should also be included. The selection of course topics and credits in the curriculum will depend on the primary thrust of the program and some topics may be covered superficially.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Technical specialty courses should include process stoichiometry and unit operations such as mass transfer, heat transfer, distillation/fractionation, and evaporation.

(2) A typical unit operations laboratory facility where students receive actual practice in the operation, maintenance, repair, testing, and checkout of process equipment is required. Such laboratory exercises must include analyses made during the laboratory operations and preparation of detailed formal written reports. Oral reporting is also recommended.

c. **Basic Sciences and Mathematics.** (Amplifies criteria section V.C.4.)

(1) A physics course, with laboratory, must be included in the program.

(2) All required mathematics topics should be taught in mathematics courses and not solely within technical science or technical specialty courses.

(3) Depending upon the objectives of the program, either the concepts of statistics or an introduction to calculus must be included.

d. **Communications.** (Amplifies criteria section V.C.5.a.)

It must be demonstrated that graduates are adequately prepared in both oral and written communications.

VI.F. PROGRAM CRITERIA FOR CIVIL ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by the American Society of Civil Engineers
(Reviewed 1995)

1. <u>Applicability.</u>

These program criteria apply to engineering technology programs including "civil," or closely related modifiers in their titles, leading to either an associate or a bachelor's degree.

2. <u>Curriculum.</u>

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

(1) Associate degree curricula must include topics in statics and strength of materials.

(2) Baccalaureate degree curricula must include topics in statics, dynamics, strength of materials, and hydraulics.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Associate degree curricula must include topics in engineering graphics, problem solving techniques, surveying, and civil engineering materials.

(2) Baccalaureate degree curricula must include topics in engineering graphics, problem solving techniques, surveying, civil engineering materials, engineering economics, soils and foundations, and in addition, a two-course analysis and design sequence in a major civil engineering technology area.

c. **Mathematics.** (Amplifies criteria section V.C.4.c.)

(1) Associate degree programs in civil engineering technology must ensure that a student understands and is able to use algebra, trigonometry, and analytic geometry. In addition, depending upon the educational objectives of the program, the basic concepts of applied statistics, advanced trigonometry, or calculus must be included.

(2) Baccalaureate degree programs in civil engineering technology must ensure that a student understands and is able to use algebra, trigonometry, analytic geometry, and applied differential and integral calculus. In addition, depending upon the educational objectives of the program, topics in applied statistics, advanced trigonometry, or differential equations might be necessary. The topics covered in mathematics should be used in the technical courses.

VI.G. PROGRAM CRITERIA FOR COMPUTER ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by the Institute of Electrical and Electronics Engineers, Inc. (Lead society, in Cooperation with the Institute of Industrial Engineers)
(Reviewed 1995)

1. <u>Applicability.</u>

These program criteria apply to engineering technology programs including "computer" or similar modifiers in their titles, leading to either an associate or a bachelor's degree.

2. <u>Curriculum.</u>

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

Technical science courses must be applications-oriented with a majority having an accompanying laboratory with emphasis on the implementation and testing of computer-based systems. Laboratory components should emphasize measurement, data collection and analysis, documentation, written report preparation and oral presentation. Advanced laboratory activities should include computer system implementation, testing, system operation and administration, and interconnectivity techniques. Course work must include the fundamentals of electricity/electronics, digital and microprocessor systems, computer systems hardware and software, and interconnectivity fundamentals.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Technical skills and techniques courses must include instruction in programming methodology and program design techniques with application on one or more computer languages (high level and assembly language) and operating systems commonly used in the practice of engineering technology. In addition, instruction must include the use of

software packages to support the design, analysis, simulation, and monitoring of digital circuits and systems, microprocessor systems, data communication networks, and computer systems. There must be a balanced treatment of computer software and hardware. Courses at the associate degree level must prepare the student for immediate employment but must include sufficient depth to enable the student to continue in upper-division studies without penalty. Upper-division course work must complement and expand lower-division work.

(2) Technical design courses must emphasize current program design techniques, documentation, and the use of manuals, handbooks, language and equipment specifications, and computers where applicable.

c. **Basic Sciences and Mathematics.** (Amplifies criteria section V.C.4.)

(1) The basic sciences must include physics (with laboratory) presented in a rigorous algebra/trigonometry environment (as a minimum).

(2) A minimum coverage in mathematics includes beginning college-level algebra, trigonometry and an introduction to calculus. Baccalaureate programs must include differential/integral calculus, and instruction in numerical methods. Applied differential equations, transform methods, linear programming, and probability/statistics are appropriate electives.

3. Financial Support and Facilities. (Amplifies criteria section V.K.4.)

Laboratory equipment, computers, and software should be of the type that would be encountered in industry and practice. Since one of the objectives of computer engineering technology programs is the development of technical skills, all students should be thoroughly familiar with the tools of computer-based software development, test and verification, simulation, data acquisition, and documentation, as well as the basic electronic analytical or measurement test equipment and specialized digital test instruments. Experience in the operation of standard or basic shop equipment such as lathes, welders, and engines does not, in itself, meet this requirement.

VI.H. PROGRAM CRITERIA FOR CONSTRUCTION ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by the American Society of Civil Engineers
(Reviewed 1995)

1. Applicability.

These program criteria apply to construction engineering technology programs or closely related modifiers in their titles, leading to either an associate or a baccalaureate degree.

2. Curriculum.

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

(1) Associate degree curricula must include topics in statics and strength of materials.

(2) Baccalaureate degree curricula must include topics in statics, strength of materials and hydraulics.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Associate degree curricula must include topics in contracts and specifications, construction materials, construction methods, cost estimating, elementary structures, engineering graphics, materials testing, and surveying.

(2) Baccalaureate degree curricula must include topics in contracts and specifications; construction materials; construction methods; concrete, steel, and wood structures design; construction surveying; construction management; cost estimating; engineering economics; engineering graphics; materials testing; plane surveying; scheduling; and soils, foundations, and earth structures.

c. **Mathematics.** (Amplifies criteria section V.C.4.c.)

(1) Associate degree programs must ensure that a student understands and is able to use algebra, trigonometry, and analytic geometry. In addition, depending on the educational objectives of the program, the study of the basic concepts of applied statistics, advanced trigonometry, or calculus must be included in the curriculum.

(2) Baccalaureate degree programs must ensure that a student understands and is able to use algebra, trigonometry, analytic geometry, and applied differential and integral calculus. The topics covered in mathematics must be used in the technical courses.

d. **Social Sciences/Humanities.** (Amplifies criteria V.C.5.b.)

Baccalaureate degree programs should include topics in macroeconomics and microeconomics.

VI.I. PROGRAM CRITERIA FOR DRAFTING/DESIGN ENGINEERING TECHNOLOGY (MECHANICAL) AND SIMILARLY NAMED PROGRAMS

Submitted by The American Society of Mechanical Engineers. (Lead society in cooperation with the Society of Manufacturing Engineers)
(Reviewed 1995)

1. Applicability.

These program criteria apply to drafting/design engineering technology programs with an emphasis on mechanical components and systems, and those with similar modifiers in their titles, leading to either an associate or bachelor's degree.

2. Curriculum.

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

(1) Associates degree curricula must include topics in materials or applied mechanics.

(2) Bachelor's degree curricula must include topics in materials, statics, strength of materials, and at least one of the following: dynamics, fluid mechanics, thermodynamics, and electrical power or electronics.

(3) Where appropriate, the courses must depend on prerequisite science and mathematics, including calculus.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Associate degree curricula must include sufficient instruction in applied drafting practice emphasizing mechanical components and systems including the fundamentals of descriptive geometry, orthographic projection, sectioning, tolerancing and dimensioning, an introduction to computer-aided graphics and design, and a course in manufacturing methods.

(2) Bachelor's degree curricula must extend the above courses in both drafting and manufacturing, and must include a course in the design of machine elements. Technical design

courses will also include open-ended design experience which integrates materials, manufacturing, design analysis, and design graphics.

(3) Use of ASME Codes & Standards or other appropriate standards, and current industrial practices should be emphasized. A familiarity with the International System of Units (SI) is required.

c. **Basic Sciences and Mathematics.** (Amplifies criteria section V.C.4.)

Physics and chemistry are recommended basic sciences. Mathematics must include topics in algebra and trigonometry and at least an introduction to calculus for the associate degree. A second course in calculus is required for a bachelor's degree.

VI.J. PROGRAM CRITERIA FOR ELECTRICAL/ELECTRONIC(S) ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by The Institute of Electrical and Electronics Engineers, Inc.
(Reviewed 1995)

1. Applicability.

These program criteria apply to engineering technology programs including "electrical," "electronic(s)," and similar modifiers in their titles, leading to either an associate or a bachelor's degree.

2. Curriculum.

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

Technical science courses must be applications-oriented with a majority having an accompanying laboratory with emphasis on measurement, data collection and analysis, documentation, and written/oral report preparation/presentation. Course work must include the fundamentals of electricity/electronics and principles of circuit analysis.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Technical skills and techniques courses must include **topics, as appropriate, to meet the stated goals and objectives of the program.**

(2) Courses at the associate degree level must prepare the student for immediate employment but must include sufficient foundation to enable the student to continue in upper-division studies without penalty. Upper-division course work must complement and expand on lower-division work.

(3) Technical design courses must stress the use of manuals, handbooks and material/equipment specifications, and computers where applicable.

c. **Basic Sciences and Mathematics.** (Amplifies criteria section V.C.4.)

(1) The basic sciences must include physics (with laboratory) presented in a rigorous algebra/trigonometry environment (as a minimum).

(2) A minimum sequence in mathematics is college-level algebra, trigonometry, and an introduction to calculus. Baccalaureate programs must include differential/integral calculus, and instruction in applied differential equations is strongly encouraged. Linear programming, numerical methods, and probability/statistics are other appropriate electives.

VI.K. PROGRAM CRITERIA FOR ENVIRONMENTAL ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by the American Academy of Environmental Engineers (Lead society in cooperation with the American Institute of Chemical Engineers; American Society of Civil Engineers; American Society of Heating, Refrigerating, and Air-Conditioning Engineers; American Society of Mechanical Engineers; the Society of Automotive Engineers, and the Society for Mining, Metallurgy, and Exploration)
(Reviewed 1995)

1. Applicability.

These program criteria apply to engineering technology programs including "environmental" and similar modifiers in their titles, leading to either an associate or bachelor's degree.

2. Curriculum.

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

(1) Associate degree curricula must include instruction in the basic mechanics of fluids, environmental chemistry, and computer science.

(2) Bachelor's degree curricula must meet the requirements of the associate degree and include instruction in the basic concepts and fundamentals of thermodynamics, engineering geology, electrical circuits and systems, and applied statistics.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Associate degree curricula must include instruction in unit operations and processes in environmental engineering.

(2) Bachelor's degree curricula must meet the requirements of the associate degree and include instruction in the elements of environmental systems analysis.

c. **Basic Sciences.** (Amplifies criteria section V.C.4.B.)

Instruction must include basic concepts in physical and organic chemistry, and microbiology.

d. **Communications.** (Amplifies criteria section V.C.5.a.)

Oral and written communications course work must include evaluation of these skills as used in environmental applications, such as presentations, laboratory reports, and special projects.

3. Industrial Advisory Committee. (Amplifies criteria section V.J.)

Environmental professionals with intimate knowledge of the full spectrum of practice in the environmental industry in the institution's regional area should be encouraged to participate in the activities of the industrial advisory committee.

VI.L. PROGRAM CRITERIA FOR INDUSTRIAL ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by the Institute of Industrial Engineers
(Reviewed 1995)

1. Applicability.

These program criteria apply to industrial engineering technology programs, and those with similar modifiers in their titles, leading to either an associate or a bachelor's degree. (Note: programs in *industrial technology*, as distinct from industrial *engi-*

neering technology, are not accredited by TAC of ABET.)

2. Curriculum.

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

A student must have knowledge of probability, statistics, engineering economic analysis, and cost control. Other essential technical sciences of which some topics must be included are material science, computer science, mechanics of solids/fluids, thermodynamics or heat power, metrology, and electricity/electronics.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) There should be a core of courses in industrial engineering technology covering skills and techniques in time/motion study, plant layout, materials handling, production control, statistical quality control, wage/salary administration, CPM/PERT, organization/management, and work simplification. Instruction in tool engineering technology, manufacturing processes, inventory control, simulation, robotics, numerical control, CAD/CAM, system/procedure analysis, optimization techniques, and software design would be helpful and appropriate. Courses at the associate degree level must prepare the student for immediate employment but must include sufficient depth to enable the student to continue in upper-division studies without penalty. Upper-division course work must complement and expand on lower-division work.

(2) The last year of the program should include a project or capstone course to integrate the knowledge learned in the technical specialties and gain experience in the art of practicing industrial engineering technology.

VI.M. PROGRAM CRITERIA FOR MANUFACTURING ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by the Society of Manufacturing Engineers
(Reviewed 1995)

1. Applicability.

These program criteria apply to engineering technology programs including "manufacturing" and similar modifiers in their titles, leading to either an associate or a bachelor's degree.

2. Curriculum. (Amplifies general criteria section V.C.)

Concepts of quality management and of continuous improvement must be integrated throughout the manufacturing program.

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

(1) Technical science **instruction** must be problem-solving oriented with the majority of courses having laboratories to reinforce understanding the principles and applications. Technical science instruction must demonstrate the use of mathematical and basic science principles and computer applications learned in prerequisite or co-requisite study.

(2) For the associate degree, it must be evident to the evaluation team that students are proficient in the following technical science areas: application of computer software, engineering materials, statics and strength of materials, and electronic and electric circuits and devices. Instruction in these areas is required to satisfy the quantitative requirements.

(3) For the baccalaureate degree, it must be evident to the evaluation team that students are proficient in all of the technical science areas enumerated for an associate degree and in at least two of the following areas: fluid mechanics or fluid power, dynamics, thermodynamics or heat transfer, control systems, instrumentation, or microprocessors or data management. Instruction in these areas is required to satisfy the quantitative requirements.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) It must be evident to the evaluation team that technical specialty instruction is preparing the associate degree graduate for employment and include sufficient depth to enable the student to continue in upper-division studies. Sequential courses must provide increasing depth. Technical specialty instruction should incorporate mathematical and basic science principles and computer applications learned in prerequisite or co-requisite study. Technical specialty instruction must incorporate use of reference material selected from those routinely used in industry.

(2) For the associate degree, it must be evident to the evaluation team that students have attained proficiency in technical graphics, quality control, and appropriate manufacturing processes and at least in one of the following technical specialties: automation, industrial organization and management, or manufacturing planning. The associate program must have at least one sequence of two or more courses using a prerequisite structure. Instruction in these areas is required to satisfy the quantitative requirements.

(3) For the baccalaureate degree, it must be evident to the evaluation team that students have attained proficiency in technical graphics, quality control and appropriate manufacturing processes, automation, computer-aided-manufacturing and engineering cost analysis, and in at least three of the following technical specialties: tooling systems, industrial organization and management, material management, metrology, manufacturing information systems, manufacturing planning, maintenance management, or environmental health and safety. The baccalaureate program must have at least three sequences of two or more courses in different subject areas, with each sequence having prerequisite structures. Instruction in these areas is required to satisfy the quantitative requirements.

(4) The institution must demonstrate that the manufacturing specialties included in the curriculum are technologically current and appropriate to the goals of the program.

(5) Through the "capstone" course(s) in the final year, the baccalaureate program must demonstrate that the goals of the program have been met, by drawing together several major elements of the design and production process. This experience should be project-oriented and comprehensive in utilizing prior instruction.

c. Basic Sciences and Mathematics. (Amplifies criteria section V.C.4.)

(1) The basic sciences must include physics with laboratory experience.

(2) For the baccalaureate degree, the basic sciences must also include chemistry.

(3) For the associate degree, the study of the concepts of statistics may be substituted for the concepts of calculus.

(4) For the baccalaureate degree, appropriate technical instruction must include applications of statistics.

VI.N. PROGRAM CRITERIA FOR MECHANICAL ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by The American Society of Mechanical Engineers
(Reviewed 1995)

1. **Applicability.**

These program criteria apply to mechanical engineering technology programs and those with similar modifiers in their titles, leading to either an associate or a bachelor's degree.

2. **Curriculum.**

- a. **Technical Sciences.** (Amplifies criteria section V.C.1.)
  - (1) Technical science courses must be applications-oriented with a majority having an accompanying laboratory with emphasize on measurement, data collection and analysis, documentation, and written/oral report preparation/presentation. Technical science courses should provide the science foundation for the technical specialties and may be included in the sequences required below. (See section 2.b.)
  - (2) Technical sciences must include topics in most of the following for the associate degree: applied materials science, applied mechanics, and applied thermal sciences. For the bachelor's degree, topics in materials science, statics, dynamics, strength of materials, fluid mechanics, thermodynamics, and electrical power or electronics must be included. Where appropriate, at both degree levels, the courses must depend on prerequisite science and mathematics.
- b. **Technical Specialties.** (Amplifies criteria section V.C.2.)
  - (1) Associate degree curricula must include a sequence of courses in at least one of the following areas: manufacturing processes, drafting and mechanical design, engineering materials, solid mechanics, fluid mechanics, and thermosciences, or electromechanical devices and controls.
  - (2) Bachelor's degree curricula must include a sequence of courses in at least three of the following areas: manufacturing processes, mechanical design, engineering materials, solid mechanics, fluid mechanics, thermosciences, electromechanical devices and controls, or industrial operations.
  - (3) Instruction provided in a series of sequential courses must provide a progressively increasing level of sophistication. Courses at the associate degree level must prepare the student for immediate employment but must include sufficient depth to enable the student to continue in upper-division studies without penalty. Upper-division course work must complement and expand on lower-division work.
  - (4) Technical design courses must stress the use of manuals, handbooks, material/equipment specifications, and computers where applicable.
- c. **Basic Sciences and Mathematics.** (Amplifies criteria section V.C.4.)
  - (1) Basic sciences must include a minimum of one course in physics for the associate degree, plus another course in a laboratory science, preferably chemistry or a second physics course. For the bachelor's degree programs, two physics courses and a chemistry course are required.
  - (2) Mathematics must include topics in algebra and trigonometry and at least an introduction to calculus for the associate degree, and the calculus must be used in some appropriate technical course work. A minimum of two courses in calculus is required for the bachelor's degree, and upper-level technical courses must include applications of the calculus where appropriate.

VI.O. PROGRAM CRITERIA FOR MINING ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by the Society for Mining, Metallurgy, and Exploration, Inc. (SME-AIME)
(Reviewed 1995)

1. **Applicability.**

These program criteria apply to engineering technology programs including "mining" and similar modifiers in their titles, leading to either an associate or bachelor's degree.

2. **Curriculum.**

- a. **Technical Sciences.** (Amplifies criteria section V.C.1.)
  - (1) Associate degree curricula must include instruction in the basic concepts of mechanics and computer science.
  - (2) Bachelor's degree curricula must include instruction in the basic concepts and fundamentals in rock mechanics, dynamics, electrical power and transmission, and fluid dynamics.
- b. **Technical Specialties.** (Amplifies criteria section V.C.2.)
  - (1) Associate degree curricula must include instruction in surface or underground mine planning, exploitation methods, and elements of mine surveying.
  - (2) Bachelor's degree curricula must meet the requirements for an associate degree and provide additional instruction in surface and underground mine planning and exploitation methods, and must include instruction in materials handling, mine environmental controls, mineral or coal processing, mine safety, and mine economics.
- c. **Basic Sciences.** (Amplifies criteria section V.C.4.b.)

  Instruction must include basic concepts in physics, chemistry, and physical geology.
- d. **Communications.** (Amplifies criteria section V.C.5.a.)

  Oral and written communications course work must be followed by evaluation of these skills as used in mining appli-cations presentations in laboratory reports and in special projects course work.

3. **Industrial Advisory Committee.** (Amplifies criteria section V.J.)

Mining professionals with intimate knowledge of the full spectrum of employment in the mining industry in the institution's regional area should be encouraged to participate in the activities of the industrial advisory committee.

VI.P. PROGRAM CRITERIA FOR NUCLEAR ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by the American Nuclear Society
(Reviewed 1995)

1. **Applicability.**

These program criteria apply to nuclear engineering technology programs and those with similar modifiers in their titles, leading to either an associate or a bachelor's degree.

2. **Curriculum.**

- a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

Technical science courses must be applications-oriented with a majority having an accompanying laboratory experience. Topics in the physical sciences must include fundamental principles, conservation laws, mass and heat transfer, and rate processes. Studies in nuclear systems and radiological safety should begin early enough in the program to allow development in subsequent studies. Problem solving must be a major element in most nuclear engineering technology courses.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Technical skills and techniques courses should emphasize those areas of study that are consistent with the institution's philosophy and the needs of the nuclear industry served by the program. Courses should emphasize nuclear processes and operations, the relation between design and operation, the human interface in operations, maintenance of nuclear systems, and the translation of engineering ideas and concepts into functioning nuclear devices, machines, structures, and systems.

(2) Technical design courses must stress the use of manuals, handbooks, material/equipment specifications, and computers where applicable. Problems should be related to current technology and should include considerations of balancing effort and accuracy as well as confidence limit estimates. Studies of nuclear plant operation must include topics in radiation protection procedures, current applicable rules and regulations, maintenance and control of nuclear systems, and quality assurance.

c. **Basic Sciences and Mathematics.** (Amplifies criteria section V.C.4.)

(1) The basic sciences must include physics (with laboratory) presented in a rigorous algebra/trigonometry environment (as a minimum).

(2) A minimum sequence in mathematics is college-level algebra, trigonometry, and an introduction to calculus. Baccalaureate programs must include differential/integral calculus, and instruction in applied differential equations is strongly encouraged. Applied probability/statistics and numerical methods are other appropriate electives.

VI.Q. PROGRAM CRITERIA FOR SURVEYING ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by the American Congress on Surveying and Mapping (Lead society, in cooperation with the American Society of Civil Engineers)
(Reviewed 1995)

1. Applicability.

These program criteria apply to surveying engineering technology programs and those with similar modifiers in their titles, leading to either an associate or a bachelor's degree.

2. Curriculum.

a. **Technical Sciences and Technical Specialties.** (Amplifies criteria sections V.C.1. and V.C.2.)

"Hands on" applications-oriented courses are required. Course work must include basic plane surveying, boundary location and relocation, surveying law, photogrammetry, control surveys, instrument use, and field practice. Additional topics such as error theory, data adjustments, remote sensing, subdivision design, and land information systems must be found in baccalaureate programs. Site planning, urban planning, construction surveying, and route surveying should be found to some extent in all programs.

b. **Technical Electives.** (Amplifies criteria section V.C.3.)

c. **Basic Sciences and Mathematics.** (Amplifies criteria section V.C.4.)

To meet the needs of many state laws and to broaden the individual's background, course work from other engineering technology areas should be included in the curriculum. Course work such as hydraulics, road design, construction estimating, construction management, engineering economics, and fundamentals of electronics would be appropriate.

(1) The basic sciences must include coverage in mechanics and basic electricity in a lecture-laboratory format.

(2) Coverage in mathematics must include college-level algebra/trigonometry and statistics. Analytic geometry and calculus would be helpful to associate degree programs. Baccalaureate programs must have coverage in differential/integral calculus, statistics, and matrix algebra.

VI.R. PROGRAM CRITERIA FOR TELECOMMUNICATIONS ENGINEERING TECHNOLOGY AND SIMILARLY NAMED PROGRAMS

Submitted by The Institute Of Electrical and Electronics Engineers, Inc.
(Reviewed 1995)

1. Applicability

These program criteria apply to engineering technology programs including "telecommunications," and similar modifiers in their titles, leading to either an associate or a bachelor's degree.

2. Curriculum

a. **Technical Sciences.** (Amplifies criteria section V.C.I.)

Technical science courses must be applications-oriented with a majority having an accompanying laboratory with emphasis on measurement, data collection and analysis, documentation, and written/oral report preparation/presentation. Course work must include the fundamentals of electricity, electronics, digital principles and telecommunications.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Technical skills and techniques courses must include topics, as appropriate, to meet the stated goals and objectives of the program.

(2) Courses at the associate degree level must prepare the student for immediate employment, and must include sufficient foundation to enable the student to continue upper-division studies without penalty. Upper-division course work must complement and expand lower-division work.

(3) Technical design courses must stress the use of manuals, handbooks and material/equipment specifications, and computers where applicable.

c. **Basic Sciences And Mathematics.** (Amplifies Criteria Section V.B.4.)

(1) The basic sciences must include physics (with laboratory) presented in a rigorous algebra/trigonometry environment (as a minimum).

(2) Associate degree curricula must have a minimum sequence in mathematics college-level algebra, trigonometry and an introduction to calculus. Baccalaureate programs must include differential/integral calculus. Instruction in the following subjects is also encouraged: Fourier series/transforms, bessel function, statistics/probabilities, applied differential equations.

d. **Communications.** (Amplifies Criteria Section V.C.5.)

Oral and written communications course work must include evaluation of these skills as used in telecommunications applications, such as presentation, laboratory reports, and special project.

VI.S. FURTHER INFORMATION

Requests for further information relative to ABET and the engineering technology accrediting program may be addressed to the Executive Director, Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202.

THE FOLLOWING SECTION OUTLINES PROPOSED CHANGES TO THE CRITERIA FOR ACCREDITING PROGRAMS IN ENGINEERING TECHNOLOGY. THESE PROPOSALS WERE APPROVED BY THE TECHNOLOGY ACCREDITATION COMMISSION (TAC), AND WERE BROUGHT BEFORE THE ABET BOARD OF DIRECTORS ON NOVEMBER 4, 1995 FOR PRELIMINARY APPROVAL. BEFORE BEING APPROVED FOR FINAL IMPLEMENTATION INTO THE ACCREDITATION PROCESS, THEY ARE PUBLISHED HERE FOR CIRCULATION AMONG THE INSTITUTIONS WITH ACCREDITED PROGRAMS AND OTHER INTERESTED PARTIES FOR REVIEW AND COMMENT.

COMMENTS WILL BE CONSIDERED UNTIL JUNE 15, 1996. THE ABET BOARD OF DIRECTORS WILL DETERMINE, BASED ON THE COMMENTS RECEIVED AND ON THE ADVICE OF THE TAC, THE CONTENT OF THE ADOPTED CRITERIA. THE ADOPTED CRITERIA WILL THEN BECOME EFFECTIVE FOLLOWING THE ABET ANNUAL MEETING IN THE FALL OF 1996 AND WILL FIRST BE APPLIED BY THE TAC FOR ACCREDITATION ACTIONS DURING THE 1997-98 ACADEMIC YEAR AND THE FOLLOWING YEARS.

COMMENTS RELATIVE TO THE PROPOSED GENERAL AND PROGRAM CRITERIA CHANGES SHOULD BE ADDRESSED TO THE ACCREDITATION DIRECTOR FOR ENGINEERING TECHNOLOGY, ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY, INC. 111 MARKET PLACE, SUITE 1050, BALTIMORE, MD 21202.

PROPOSED CHANGES TO THE GENERAL CRITERIA

In the next edition of these criteria, it is proposed to change section II.A.3. to read as follows:

Only individual programs are accredited, rather than institutions, for it is recognized that programs of different standards and objectives may be found at the same institution. When a multi-campus institution presents programs for accreditation, each campus will be considered as a separate institution in the evaluation process. In order for a program to be accredited, all routes to completion of the program must be accreditable.

In the next edition of these criteria, it is proposed to change section II.A.3.b. to read as follows:

II.A.3.b. Evening and Off-Campus Programs — Evening and off-campus programs may be accredited as integral with the regular on-campus day program, if they follow the same curriculum, use the same or equivalent laboratory facilities and equipment, and are subject to the same supervision and control of academic standards. The institution must demonstrate that evening and off-campus programs are conducted to the same standards of subject matter coverage and rigor of student work and grading.

In the next edition of these criteria, it is proposed to change sections III.A. Questionnaire and III.B. On-site Visit to read as follows:

III.A. Questionnaire

One of the first steps in the accreditation process for a program is the submission by the institution of information and data in the form of a self-study questionnaire and its review by TAC of ABET prior to an on-site visit. The self-study questionnaire must include day and evening programs and all incorporated options and off-campus offerings.

III.B. On-site Visit

The on-site visit team will examine all incorporated day, evening, option and off-campus offerings.

In the next edition of these criteria, it is proposed to change sections V.A. Program Level and Course Requirements to become V.B. Program Content and Orientation and V.B. becomes V.A. to read as follows:

V.A. Program Content and Orientation

V.A.1. The program content should provide an integrated educational experience directed toward development of the ability to apply pertinent knowledge to the solution of practical problems in the graduate's engineering technology specialty.

V.A.2. ABET requires a high degree of specialization for engineering technology programs with field orientation rather than task orientation. The technical orientation of specialization should be manifested by faculty qualifications and course content.

V.A.3. Programs must have written goals which are consistent with overall institutional goals. These goals must, as a minimum, focus on the student body served, resource allocation, and other factors directly affecting the program. Articulation of goals should be accomplished through specification of objectives by which achievement toward goals can be measured. Programs must demonstrate achievements through various methods, e.g., student outcome assessments, graduate career performance and employer feedback measures.

V.A.4. Programs must have plans for continuous improvement. The visiting team will be looking for evidence which demonstrates implementation of continuous improvement processes and procedures for each program.

V.B. Program Level and Course Requirements

Engineering technology programs may be accredited at the associate degree level or at the baccalaureate level. Differential criteria are specified as the minimum course requirements for each level. This section of the criteria relates to the program performance in producing graduates from programs meeting minimum course criteria.

V.B.1. Accreditable **associate degree** programs must be characterized by the following minimums in course requirements:

V.B.1.a. A minimum of 64 semester hour credits or 96 quarter hour credits for a two-year **associate degree**.

V.B.1.b. 32 semester hour or 48 quarter hour credits of technical courses including technical sciences, technical specialties, and technical electives.

V.B.1.c. 16 semester hour or 24 quarter hour credits of an appropriate combination of basic sciences and mathematics of the type, level, and subject coverage specified in these criteria and applicable program criteria. The basic sciences component must include at least 4 semester hour or 6 quarter hour credits in areas specified in section V.C.4.b. below. The mathematics component must include at least 8 semester hour or 12 quarter hour credits in areas specified in section V.C.4.c. below. The remainder of the requirement may be met by appropriate course work in either basic sciences or mathematics.

V.B.1.d. 9 semester hour or 13 quarter hour credits consisting of social sciences and/or humanities and instruction in written and oral communications appropriate to the program, of which at least 6 semester hour or 9 quarter hour credits are the study of communications. Some study in social sciences and/or humanities must also be included in the total requirement.

V.B.1.e. The balance of the program should be designed to achieve an integrated and well-rounded engineering technology program. The additional time is available for the implementation of the educational objectives of the institution and/or individual as they relate to ensuring adequate educational preparation for the graduate to function as an engineering technician. This includes the ability to use the computer in solving technical problems. Additional course work in engineering technology or related areas will be needed to fulfill such an objective. The institution must address such needs and objectives in developing the program and its contents. A maximum of 4 semester hours or 6 quarter hours of cooperative education experience, to enhance the skills of the technician, may be included in this portion of the curriculum toward meeting the minimum number of credit hours specified in section V.A.1.a. above, provided it meets the requirements of section V.C.7. below.

V.B.2. Accreditable **baccalaureate** programs must be characterized by the following minimums in course requirements:

V.B.2.a. A minimum of 124 semester hour credits or 186 quarter hour credits for a **baccalaureate degree.**

V.B.2.b. 48 semester hour or 72 quarter hour credits of technological courses including technical sciences, technical specialties, and technical electives.

V.B.2.c. 24 semester hour or 36 quarter hour credits of an appropriate combination of basic sciences and mathematics of the type, level, and subject coverage specified in these criteria and applicable program criteria. The basic sciences component must include at least 8 semester hour or 12 quarter hour credits in areas specified in section V.C.4.b. below. The mathematics component must include at least 12 semester hour or 18 quarter hour credits in areas specified in section V.C.4.c. below. The remainder of the requirement may be met by appropriate course work in either basic sciences or mathematics.

V.B.2.d. 24 semester hour or 36 quarter hour credits consisting of social sciences and/or humanities and instruction in written and oral communications appropriate to the program, of which at least 9 semester hour or 13 quarter hour credits are the study of communications and at least 8 semester hour or 12 quarter hour credits are in social sciences and/or humanities. The remainder of the requirement may be met by appropriate course work in either area.

V.B.2.e. The balance of the program should be designed to achieve an integrated and well-rounded engineering technology program. The additional time is available for the implementation of the educational objectives of the institution and/or the individual as they relate to ensuring adequate educational preparation for the graduate to function as an engineering technologist. This includes the ability to use the computer in solving technical problems. Additional course work in engineering technology or related areas will be needed to fulfill such an objective. The institution must address such needs and objectives in developing the program and its contents. A maximum of 8 semester hours or 12 quarter hours of cooperative education experience, to enhance the professional development of the technologist, may be included in this portion of the curriculum toward meeting the minimum number of credit hours specified in section V.A.2.a. above, provided it meets the requirements of section V.C.7. below. However, no more than half of the maximum (4 semester or 6 quarter hours) co-op credit may be counted in the upper division (junior/senior years) of the program.

V.B.3. ABET encourages innovative or novel program arrangements. Non-traditional programs will be evaluated against the above criteria to ascertain that the programs satisfy the intent of the minimums established.

In the next edition of these criteria, it is proposed to change section V.F. Faculty to read as follows:

V.F. Faculty

This section of the criteria relates to the technical faculty members' adequacy in credentials, numbers, and competence. The technical faculty, which may be the single most important factor in an educational program, will be evaluated individually and as a whole. For those programs which incorporate evening or off-campus offerings, the evening and off-campus faculty members are considered as part of the overall program faculty and must satisfy the provisions of this section of the criteria. Strong programs will have technical faculty members whose qualifications exceed what is described here as "basic credentials."

In the next edition of these criteria, it is proposed to change section V.F.2. to read as follows:

V.F.2. In exceptional cases there may be technical faculty members who satisfy the intent of the above minimums without literally satisfying the criteria. TAC of ABET may recognize these exceptions if the institution convincingly demonstrates the equivalence.

PROPOSED CHANGES TO TECHNOLOGY PROGRAM CRITERIA

In the next edition of these criteria, it is proposed that the statements under "b. Technical Specialties" in the "2. Curriculum" section of the Program Criteria for Bioengineering Technology and Similarly Named Programs be changed to read as follows:

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Technical skills and techniques courses must include, topics, as appropriate, to the stated goals and objectives of the program.

(2) Courses at the associate degree level must prepare the student for immediate employment, and must include sufficient foundation to enable the student to continue in upper-division studies without penalty. Upper-division course work must complement and expand lower-division work. All upper-division programs must include at least one 3-semester credit course in hospital internship.

(3) Technical design courses must stress the use of manuals, handbooks, and material/equipment specifications, and computers where applicable.

c. **Basic Sciences and Mathematics.** (Amplifies criteria section V.C.4.)

(1) The basic sciences must include physics and chemistry both (with laboratory) presented in a rigorous algebra/trigonometry environment (as a minimum).

In the next edition of these criteria, it is proposed that the statements under "a. Technical Science" in the "2. Curriculum" section of the Program Criteria for Computer Engineering Technology and Similarly Named Programs be changed to read as follows:

2. Curriculum.

a. Technical Sciences. (Amplifies criteria section V.C.1.)

Technical science courses must be applications-oriented with a majority having an accompanying laboratory with emphasis on measurement, data collection and analysis, documentation, and written/oral report preparation/presentation. course work must include the fundamentals of electricity/electronics and digital Principles.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Technical skills and techniques courses must include, topics, as appropriate, to meet the stated goals and objectives of the program. They must be a balanced treatment of computer software and hardware evidenced by courses reflecting each aspect of the discipline.

(2) Courses at the associate degree level must prepare the student for immediate employment, and must include sufficient foundation to enable the student to continue in upper-division studies without penalty. Upper-division course work must complement and expand lower-division work.

(3) Technical design courses must emphasize flow charting, documentation, and the use of manuals, handbooks, language/equipment specifications, and computers where applicable.

c. **Basic Sciences and Mathematics.** (Amplifies criteria section V.C.4.)

(1) The basic sciences must include physics (with laboratory) presented in a rigorous algebra/trigonometry environment (as a minimum).

(2) A minimum coverage in mathematics includes beginning college-level algebra, linear algebra/matrices, and trigonometry. Baccalaureate programs must include differential/integral calculus, and instruction in numerical methods is strongly encouraged. Applied differential equations, transform methods, linear programming, and probability/statistics are appropriate electives. application-oriented textbooks are preferred.

In the next edition of these criteria, it is proposed that the statements under "a. Technical Sciences" and "b. Technical Specialties" in the "2. Curriculum" section of the Program Criteria for Drafting/Design Engineering Technology and Similarly Named Programs be changed to read as follows:

2. **Curriculum.** (Amplifies general criteria section V.B., V.C. and V.D.) Procedures must exist and be utilized to ensure technical currency and continuous improvement in the program.

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

(1) Technical science courses must be applications oriented with a majority having an accompanying laboratory to reinforce understanding of principles and applications. The laboratory should emphasize measurement, data collection analysis, documentation, and written/oral report preparation /presentation. Technical science courses must provide the science foundation for the technical specialties.

(2) Associate's degree curricula must include topics in materials and applied mechanics.

(3) Bachelor's degree curricula must include topics in materials, statics, and strength of materials. The following topics are also recommended: dynamics, fluid mechanics, thermodynamics, and electrical power electronics.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Principles learned in prerequisite or co-requisite courses in mathematics, basic sciences and computers must be incorporated into technical specialty instruction.

(2) Technical skills and technique courses must include topics that are appropriate to meet the stated goals and objectives of the program.

(3) As a minimum, associate degree curricula must include instruction in drafting practice emphasizing current industry standards and applications to mechanical components and systems, descriptive geometry, orthographic projection, sectioning, tolerancing and dimensioning, computer aided graphics and design and manufacturing methods. At least one sequence of courses using a prerequisite structure must be included.

(4) Bachelor degree curricula must extend the above course topics in both drafting and manufacturing, and must include instruction in the design of machine elements and should include instruction in current three dimensional computer representations. A baccalaureate program must have at least

three sequences of two or more courses in subject areas having a prerequisite structure.

(5) Technical design courses must stress the use of manuals, handbooks, material/equipment specifications, and also computers where applicable. Appropriate codes and standards from current industrial practice must be emphasized. Open-ended design experiences which integrate materials, manufacturing, design analysis, graphics, or other topics from prerequisite course work must be included in some upper division courses. Concepts relating to the environmental and economic impacts of design should be introduced.

c. **Basic Sciences and Mathematics.** (Amplifies criteria section V.C.4.)

Basic sciences must include of one course in physics for the associate degree, plus another course in a laboratory science, preferably chemistry or a second physics course. For the bachelor degree program, courses in both physics and chemistry are required. Mathematics must include topics in algebra and trigonometry and at least an introduction to calculus for the associate degree. A second course in calculus is required for a bachelor degree. Technical courses must include applications of basic sciences and mathematics.

In the next edition of these criteria, it is proposed that the statements under "a. Technical Sciences", "b. Technical Specialties" and "c. Basic Sciences and Mathematics" in the "2. Curriculum" section of the Program Criteria for Mechanical Engineering Technology and Similarly Named Programs be changed to read as follows:

2. Curriculum. (Amplifies general criteria section V.B., V.C., and V.D.) Procedures must exist and be utilized to ensure technical currency and continuous improvement in the program.

a. **Technical Sciences.** (Amplifies criteria section V.C.1.)

(1) Technical science courses must be applications oriented with a majority having an accompanying laboratory to reinforce understanding of principles and applications. The laboratories should emphasize measurement, data collection and analysis documentation, written/oral report preparation/presentation. technical science courses must provide the science foundation for the technical specialties.

(2) Associate degree curricula must include topics in materials, applied mechanics and applied thermal science*.

(3) Bachelor degree curricula must include topics in materials, statics, dynamics, strength of materials, fluid mechanics, thermodynamics, and electrical power or electronics.

b. **Technical Specialties.** (Amplifies criteria section V.C.2.)

(1) Technical specialty instruction must prepare the associate degree graduate for immediate employment and include sufficient depth to enable the student to continue in upper-division studies. Sequential courses must provide increasing depth. Technical specialty instruction must incorporate mathematical and basic science principles and computer applications learned in prerequisite or co-requisite study.

(2) Technical skills and technique courses must include topics that are appropriate to meet the stated goals and objectives of the program.

(3) As a minimum, associate's degree curricula must include instruction in manufacturing processes, mechanics, drafting and mechanical design, computer aided engineering graphics, engineering materials, and fundamentals of electric circuits*. At least one sequence of courses using the prerequisite structure must be included.

(4) Bachelor degree curricula must extend the above course topics in mechanical design and must include at least three sequences of two or more courses in subject areas having a prerequisite structure.

(5) Technical design courses must stress the use of manuals, handbooks, material and equipment specifications, and also computers where applicable. Appropriate codes and standards from current industrial practice must be emphasized. Open-ended design experiences which integrate materials, manufacturing, design analysis, graphics, or other topics from prerequisite course work must be included in some upper division courses. Concepts relating to the environmental and economic impacts of design should be introduced.

c. **Basic Sciences and Mathematics.** (Amplifies criteria section V.C.4.)

(1) Basic sciences must include a minimum of one course in physics for the associate degree, plus another course in a laboratory science, preferably chemistry or a second physics course. For the bachelor's degree programs, courses in both physics and chemistry are required.

(2) Mathematics must include topics in algebra and trigonometry and at least an introduction to calculus for the associate degree. A second in calculus is required for a bachelor's degree. Technical courses must include applications of basic sciences and mathematics.

***IF THESE TOPICS ARE NOT COVERED SUFFICIENTLY IN SCIENCE COURSE WORK.**

APPENDIX D

APPENDIX D

SCHEDULE OF EVENTS FOR TAC/ABET ACCREDITATION PROCESS – MET PROGRAM

Date/ Deadline	*From*	*To*	*Action or Event*	*Status/Who*
1/31/96	***FSU***	ABET	FSU requests evaluation by ABET	Completed/***FSU***
2/6/96	ABET	***FSU***	ABET sends questionnaire and instructions to FSU	Completed/ABET
5/10/96	ABET	-	ABET appoints team chair (TC)	Completed/ABET
6/28/96	***FSU***	ABET	FSU forwards preliminary copy of volumes I and II of Self-Study Questionnaire to ABET	Completed/***FSU***
9/2/96	TC	***FSU***	Complete arrangements for TAC team evaluation visit	*Dates are October 7-8, 1996*
9/2/96	***FSU***	-	Confirm availability of personnel to meet with Team	Completed ***FSU***
9/2/96	TC	TM	Select team members (TM)	Completed/TC
9/2/96	TC	*FSU*	Obtain concurrence on visiting team	Completed ***FSU***
9/4/96	***FSU***	TC TM	Delivery of final copy of volumes I and II of the Self-Study Questionnaire to team chair and team members	Completed ***FSU***
8/95 to 10/4/96	***FSU***	-	Prepare course materials for TAC team review: Texts, syllabi, handouts, samples of student work	Completed ***FSU***
10/6-10/8/96	TC, TM	***FSU***	Conduct Visit to FSU by TAC evaluation team (See next page)	TAC Team ***FSU***
10/28/96	TC	ED CC ABET	Team chair submits draft visitation report to: Editor (ED) Chair of Technology Accreditation Commission (CC) ABET	TC
11/11/96	ED	CC	Editor forwards report to the Chair of TAC	ED
11/25/96	CC	ABET	Chair of TAC forwards report to ABET	CC
2/10/97	ABET	***FSU***	ABET sends FSU draft of preliminary visitation report	ABET
3/27/97	***FSU***	TC ED CC ABET	FSU responds to preliminary visitation report	Completed ***FSU***
6/1/97	ABET	TAC	ABET prepare summary report books for action by TAC	ABET
7/1/97	TAC	ABET	TAC meets and takes accreditation action	TAC
7/15/97	ABET	***FSU***	ABET gives FSU preliminary notification	ABET
9/4/97	ABET	***FSU***	ABET sends FSU accreditation letter and final visitation report	ABET
9/4/97	ABET	***FSU***	*New accreditation takes effect*	Completed
1/31/02	***FSU***	ABET	Deadline to request ABET for a reaccreditation visit	***FSU***
9/30/03			*Present TAC of ABET accreditation expires.*	

TAC ACCREDITATION TEAM VISIT TO FSU – MET PROGRAM

Date/ Deadline	***Action or Event***		**Arrangements/Location**
10/6-8/96		**Conduct Visit to FSU by TAC Committee**	
Sunday 10/6/96		Arrive Team assembles in executive session	*Holiday Inn* Conference Room *Conference Center*
Monday 10/7/96	8:30 am	Brief meeting of Team with FSU Administration Review visit and post-visit procedure and respond to questions	Conference Room *Rankin Center*
	9:00 am	Team proceeds with individual assignments Faculty are available for interviews	302 *Swan Building*[1]
	12:00 pm	Luncheon with Team and FSU personnel Faculty members: C. Drake, G. Olsson Administration Officers: D. Chase, M. Curtis, T. Oldfield, W. Sederburg Industry Advisory Committee members: M. Potts, Dr. Thiruvengadam, D. Lampen, V. Ursini	Lunch Party of 14 Room 217 *Rankin Center*
	1:30 pm	Team continues with assignments	302 *Swan Building*
	7:30 pm	Team assembles for review and evaluation of the information obtained the first day	Conference Room *Conference Center*
Tuesday 10/8/96	8:30 am	Team continues with assignments	302 *Swan Building*
	12:00 pm	Luncheon in private location (Team members only) Team assembles in executive session	Private Dining Room *Rankin Center*
	1:30 pm	Team members' reports will be completed and given to the team chair	
	2:30 pm	Oral report (exit interview) Team meets with President Sederburg and his designees to review the significant findings of the team. This gives FSU an opportunity to provide additional pertinent material or correct any misconceptions, as necessary. ABET requests that verbatim recordings not be made.	Conference Room *Rankin Center*

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[1] WORK ROOM FACILITIES
- 302 Swan building (provide Team with keys)
- 2 computers and a laser printer
  - word processing
  - view student spreadsheet assignments
  - run student programs
- VCR and monitor
  - view student oral presentations
  - view instructional video tapes
- Materials (including texts, syllabi, handouts, and samples of student work) for 16 courses are organized on adjacent tables

APPENDIX E

INFORMATION FOR HOST INSTITUTIONS

TECHNOLOGY ACCREDITATION COMMISSION
of the
ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY
111 Market Place, Suite 1050
Baltimore, MD 21202-4012
(410) 347-7724

Mechanical Engineering Technology

APRC 1997-1998

Section 4 of 4

ABET TECHNOLOGY ACCREDITATION COMMISSION

INFORMATION FOR HOST INSTITUTIONS

I. PRE-VISIT PREPARATION

The purpose of this manual is to provide information for those institutions that have requested or are interested in an evaluation of their engineering technology programs by the Technology Accreditation Commission (TAC) of the Accreditation Board for Engineering and Technology (ABET). This manual is to be used in conjunction with the current edition of Criteria for Accrediting Programs in Engineering Technology, which is the official document promulgating the standards to be met by accreditable engineering technology programs at either the associate or bachelor's degree level. The guiding principle of these procedures and the criteria is the desire to achieve a sound engineering technology education with a view to the promotion of the public welfare through the development of better-educated engineering technologists and engineering technicians.

Only those programs which can legitimately claim to lead to a degree in some field of *engineering technology* are within the scope of the TAC's accreditation activity.

The preparations and procedures which precede a visit are as follows:

A. On initial contact by a school, the following materials are provided by ABET headquarters:

1. Request for Evaluation and Directory Information forms.
2. Criteria for Accrediting Programs in Engineering Technology, including program criteria for specific disciplines.
3. Fee Schedule.
4. Other material as appropriate to each case.

B. Following a review of this information, the school should determine if its programs meet the criteria and applicable program criteria, and whether accreditation should be sought at the associate or bachelor's degree level. If further information is needed, ABET headquarters should be contacted.

C. Following a determination by the school of the accreditation to be requested, the Request for Evaluation and Directory Information forms, which constitute the official request from the school, are completed and sent to ABET headquarters. Requests are held until December or January each year if received earlier.

D. Between December and the following March, on receipt of the school's Request for Evaluation, ABET headquarters sends the following materials:

1. Questionnaire for Review of Programs in Engineering Technology.
2. Information for Host Institutions.
3. Criteria for Accrediting programs in Engineering Technology (latest edition, including program criteria).
4. Fee schedule (current edition).
5. Other material as appropriate to each case.

E. The institution should immediately begin to accumulate materials required for the questionnaire, examples of student work (see item K.5. below) and evidence of employer satisfaction with graduates and graduate satisfaction with employment, as specified in the criteria.

F. ABET will invoice the institution for the accreditation fee, based on the number of team members needed to review the institution and the programs to be evaluated.

G. The school should complete the Questionnaire for Review (Volume I for the engineering technology unit and Volume II for each program) according to the instructions in that document. The ABET office copy should be provided as soon as it is completed and not later than July 1st. The visiting team's copies **must be received by the team members at least 30 days** before the scheduled visit. Failure to provide this material on time will jeopardize the conduct of the visit.

H. During the summer, the Technology Accreditation Commission (TAC) appoints visiting team chairs for the forthcoming accreditation cycle. By August 15th, the team chair will contact the school official designated in the Directory Information form (step C. above) to set a tentative date for the visit. The schedule requires that visits be conducted between September and January. Later visits can be allowed only under exceptional circumstances, subject to approval by the team chair and the chair of the TAC. It is urged that the institution make arrangements for a visit as early in the period as possible. A benefit of this, from the school's standpoint, is that a greater amount of time is available to the school to study the preliminary report of the evaluation team and to provide factual information documenting any corrections made prior to accreditation action by the TAC.

I. An evaluation team will be selected by the team chair, consisting of properly qualified individuals from the program evaluators lists for the programs to be visited. The school will be advised of the proposed membership of the team and given the opportunity to reject any member proposed, including the team chair, if it sees a potential conflict.

J. The team chair will be in further contact with the school regarding travel arrangements, hotel reservations and other details.

K. The host institution should make the following arrangements for the evaluation team.

1. **Lodging**
   - a. Lodging for the team members should be located convenient to the school and to a restaurant, and should be comfortable but not luxurious.
   - b. Normally, firm reservations for single rooms for each team member should be made for the night previous to the first day on campus. If an extended visit is determined to be necessary (see L. below) or multiple locations are to be visited requiring separate accommodations, the team chair will advise of any additional reservations to be made.
   - c. The reservation clerk should be instructed to acknowledge the reservation directly to each team member.
   - d. Costs of lodging and meals for the visiting team are covered by ABET as part of the regular accreditation fee. Individual team members are reimbursed by ABET for expenses they incur.
2. **Conference Rooms**
   - a. It will be necessary to have suitable accommodations for a meeting of all team members on the night prior to the visit and again on the night of the first day. Preferably, this meeting room should be at the place of lodging and should provide work space for the team members. The team chair's room may serve this purpose for a small team.
   - b. The host institution should make available a headquarters room on the campus for the private use of the evaluation team during the visit. (Also see 5 below.)
3. **Meal Arrangements on Campus**
   See item III.D. below regarding hosting. For all other meals, the visiting team should be directed to a facility customarily used by the faculty. Some arrangement for privacy would be appreciated.
4. **Transportation**
   - a. The team members should be notified of transportation arrangements from the point of arrival to the lodging.
   - b. If the lodging is not within easy walking distance of the institution, the team chair should be so informed so that transportation arrangements can be made.
5. **Display Materials**
   The following materials should be displayed in the headquarters room on the campus.
   - a. In order to make a qualitative evaluation of a program, it is necessary that the institution exhibit teaching materials such as course outlines and textbooks for *all courses required for graduation*.
   - b. Sufficient examples of student work showing a range of grades for assignments including homework, quizzes, examinations, drawings, laboratory reports, projects, and samples of computer usage from *all technical, mathematics and science courses* must be available to the visiting team for the entire campus visit.
   - c. Examples must also be presented to demonstrate compliance with the requirement for student competency in written and oral communications as specified in section V.C.5.a. of the ABET criteria.
   - d. All materials must be current.

L. **Extended Visit**

In special circumstances, the team chair may require that the visit be extended to assure a quality evaluation. The team chair should preferably determine the situation in advance, request permission for an extended visit from the TAC chair and advise the appropriate institution official prior to the visit. If a situation is discovered during the visit which makes an extension desirable, the team chair should consult with the TAC chair by telephone, if possible.

II. EVALUATION TEAM RESPONSIBILITIES DURING VISIT

A. The team members will inspect the facilities and interview school personnel and students, and will complete forms containing the necessary information about the programs and service areas being visited, including program facilities, faculty and support personnel, objectives of each program, analysis of the program, graduate employment, future plans, strengths and weaknesses of the program, and other factors relevant to the accreditation of the program.

B. The team chair will collect information on the administration, overall faculty policies, general physical facilities, student services, long-range plans, major strengths and weaknesses, and other relevant factors.

C. The team members are required to complete their individual reports and deliver them to the team chair prior to the end of the visit.

III. CONDUCT OF THE VISIT

The following is a typical evaluation team schedule. Appropriate modifications will be arranged with the institution and the team by the visiting team chair.

A. Afternoon or evening session prior to the visit - time to be specified by the team chair.

The team will assemble in executive session.

B. Morning of the first day—8:30 a.m.

The team will have a brief meeting with the campus administrative officers to review the visit and post-visit procedure and to respond to general questions.

C. Morning of the first day—9:00 a.m.

The team will proceed with individual assignments. It is expected that all faculty members will be available for interview by the curriculum evaluator. It will be helpful to have the faculty schedules available to the team prior to arrival on campus.

D. Luncheon, first day—12:30 p.m.

If the institution desires to afford an opportunity for the team to meet key faculty members, administrative officers, industrial advisory committee members, or other institution officials, it may arrange a luncheon for the team. (Under some circumstances, it may be appropriate to schedule a dinner or breakfast meeting at another time in the visit.) ABET requests that any hosting of the team be limited to this one meal.

E. Afternoon of the first day—1:30 p.m.

Each team member will continue with individual assignments.

F. Evening of the first day—7:30 p.m.

The team will assemble for review and evaluation of the information obtained during the first day.

G. Morning of the second day—8:30 a.m.

Each team member will continue with individual assignments.

H. Luncheon, second day—12:30 p.m.

The team will assemble in executive session. A private location should be made available.

I. Afternoon of the second day—1:30 p.m.

Team members' reports will be completed and given to the team chair before the oral report (exit interview).

J. Afternoon of the second day—3:30 p.m.

Oral report (exit interview). The team chair and all the team members will meet with the chief administrative officer of the institution and such other personnel as he or she may wish to assemble to review the significant findings of the team. This will give the institution an opportunity to provide additional pertinent material or correct any misconceptions, as necessary. In order to preserve the informality of this meeting, ABET requests that verbatim recordings of the exit interview not be made.

IV. OBLIGATION OF TRUST

In accepting his or her appointment, each member of the evaluation team has assumed an obligation of trust to guard as **UTTERLY CONFIDENTIAL** all matters involved. Such matters are discussed only through channels established by TAC of ABET for that express purpose.

V. PUBLIC RELEASE POLICY

The following policies apply to all public disclosures concerning TAC of ABET accreditation:

A. All references to TAC of ABET accreditation of engineering technology programs must (1) avoid any confusion between engineering and engineering technology, (2) refer only to those programs which are currently accredited by TAC of

ABET, and (3) not imply accreditation or endorsement of any non-accredited program or of an institution as a whole, since TAC of ABET accredits individual programs, not entire departments or institutions.

B. Any reference to TAC of ABET accredited programs must be completely factual and professional in tone. The reference itself must include the phrase "accredited by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology."

C. The ABET Board of Directors has approved the following additional policy statements.

> "Accreditation by TAC of ABET is based on satisfying minimum educational criteria. As a measure of quality, it assures only that an accredited program satisfies the minimum standards. The various periods or terms of accreditation do not represent a relative ranking of programs in terms of quality. At no point is an institution allowed to publish or imply the term or period of accreditation. Public announcement of the accreditation action should only relate to the attainment of accredited status. Because accreditation is specific to a program, all statements on accreditation status must refer only to those programs that are accredited. No implication should be made by an announcement or release that accreditation by TAC of ABET applies to any programs other than the accredited ones.
>
> "College catalogs and similar publications must clearly indicate the programs accredited by TAC of ABET as separate and distinct from any other programs or kinds of accreditation. No implication should be made in any listing that all programs are accredited because of an institution's regional or institutional accreditation. Accredited engineering technology programs should be specifically identified as 'accredited by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology.'
>
> "Direct quotation in whole or in part from any statement by TAC of ABET to the institution is unauthorized. Correspondence and reports between the accrediting agency and the institution are confidential documents and should only be released to authorized personnel at the institution. Any document so released must clearly state that it is confidential. Wherever institutional policy or state or federal laws require the release of any confidential documents, the entire document must be released.
>
> "If accreditation is withdrawn or discontinued, the institution shall no longer refer to the program as accredited."

VI. POST-VISIT ACTIVITIES

A. Technology Accreditation Commission of ABET

1. The team chair prepares a draft visitation report utilizing the information provided by the school and gathered by the team during the visit.
2. This report and supporting data forms are sent to a designated TAC officer who reviews and edits the contents for format and consistency with ABET policies.
3. The edited report is then forwarded to the chair of the Technology Accreditation Commission for further review and editing. The draft visitation report is then typed by ABET headquarters and sent to the dean or appropriate academic administrator of the school, with copies to the TAC personnel concerned. The institution has 45 days in which to study the report and prepare a response.
4. The institution's response is reviewed by the team chair, the editor, and the TAC chair, as a result of which review the draft visitation report may be revised as warranted. (See B.1. below.)
5. The Technology Accreditation Commission meets annually in June or July to deliberate the findings of the visiting team as presented by its team chair. The school's response to the draft visitation report is included in the commission's consideration, and the final accreditation decision is voted on by the commission as a whole.
6. The institution may submit additional information to the team chair for consideration up to two weeks prior to the annual decision-making meeting. Any material to be considered by the Commission *must be in writing*.
7. Immediately following the commission's meeting a letter is sent by the ABET executive director to the dean or appropriate academic administrator as preliminary notification of the accreditation action(s) for the program(s) visited.
8. Should the institution desire to appeal a Commission ruling of not to accredit (the only appealable action), ABET will consider only conditions known to the Commission at the time of the decision.
9. The commission's decision is subsequently reported to the chief executive officer of the school in a formal letter from the president of ABET, enclosing the final visitation report. In cases where the action is not to accredit, an executive summary of the reasons for the action will accompany the final report. The president of ABET or his/her designated representative will conduct an independent review of the final report for all not-to-accredit actions.

Accredited programs are listed in the *ABET Accreditation Yearbook* (prior to 1991, known as *ABET Annual Report)* for as long as the accreditation remains in effect.

10. The report and supporting data provided by the visiting team, the institution's response, and the president's letter become part of the official record maintained at ABET headquarters.

B. Institution

1. After the visiting team leaves the campus, there is no further action required by the school until the TAC draft visitation report has been received. The school administration is requested to acknowledge receipt of the report, and is encouraged to submit comments on the information included therein, as stated in the ABET criteria.

> "The operating policy of the TAC of ABET has been to base its accreditation actions on the status of the respective program at the time of the on-site visit. However, the commission had maintained a flexible attitude toward the addition or modification of discrete items, based on conditions altered after the team visit but prior to the commission's accreditation deliberations. Weaknesses existing at the time of the visit are considered to have been corrected only when the correction or revision has been made effective, is substantiated by official documents signed by the responsible administrative officers, or other evidence required by TAC of ABET is provided. Where action to correct a problem has been initiated but not completed to the satisfaction of TAC of ABET, or where only indications of good intent are given, the action will not be considered in current accreditation deliberations."

2. The submission of the draft visitation report to the school authorities is ABET's method of ensuring that the evaluation presented by the Technology Accreditation Commission is complete and factual, from the viewpoint of both the commission and the school.
3. The institution should not attempt to contact individual team members either formally or informally after the visit has been completed. Any questions should be addressed only to the team chair, with a copy to ABET headquarters, or directly to ABET headquarters if appropriate.
4. The institution may appeal a not-to-accredit action within 30 days of receiving formal notification of the action. The chief executive officer of the institution must submit the appeal to ABET in writing and must present reasons why the decision is inappropriate. Two situations relative to the Technology Accreditation Commission decision may apply as follows: (a) errors of fact, or (b) failure to conform to ABET's published criteria, policies, and/or procedures.
5. As part of the appeal, an institution may request either an immediate revisit (in cases where substantive change is documented), or reconsideration (in cases where major, documented errors of fact are involved) of the action. The TAC executive committee will consider the request and may approve it by granting a revisit, or reverse the not-to-accredit decision as appropriate. If either type of request is denied by the executive committee, the institution retains the right to appeal to the ABET Board of Directors. In all cases, the ABET executive director is available for consultation to determine the best course of action for the institution. Such consultation is strongly encouraged.
6. It is the obligation of the institution to report to ABET any significant changes in the status of an accredited program during the term of accreditation.

TECHNOLOGY ACCREDITATION COMMISSION
SIMPLIFIED SCHEDULE OF EVENTS FOR A TYPICAL EVALUATION VISIT

Date	*From*	*To*	*Action or Event*
Nov-Dec (X-1)	ABET	Inst	Remind of expiring accreditation
Jan-Mar (X)	Inst	ABET	Request evaluation
	ABET	Inst	Send questionnaire, criteria, etc.
June-July (X)	ABET	—	Appoint team chair (TC)
July 1 (X)	Inst	ABET	Complete and forward Vols. I and II of Self-study Questionnaire
July-Aug 15 (X)	TC	Inst	Contact Institution
	ABET	SB, PB	Notify name of team chair
July-Sept (X)	TC	Inst	Complete visit arrangements
	TC	TM, SB	Select team members (TM), arrange for observers where appropriate
	TC	Inst	Obtain concurrence on visiting team
NLT 30 days before visit	Inst	TC, TM	Deliver completed questionnaire
Sept (X) to Jan (X+1)	TC, TM	Inst	Conduct visit (V date)
V	TM	TC	Submit individual report(s)
V+20*	TC	ED, CC, ABET	Submit draft visitation report and supporting material
Within 14 days*	ED	CC	Edit and forward report
Within 14 days*	CC	ABET	Edit and forward report
Jan-Mar (X+1)	ABET	Inst (copy to TC, ED, CC)	Type and forward draft preliminary visitation report (PVR)
	ABET	TC	Return synopsis report pending institution's response
Within 45 days	Inst	TC, ED, CC, ABET	Respond to draft PVR
Within 7 days**	TC	ED	Forward revised PVR report (RVR) and recommendations to reflect institution's response
Within 7 days**	ED	CC	Review and forward RVR and recommendations
Within 7 days**	CC	ABET	Review and forward RVR and recommendations
June (X+1)	ABET	—	Prepare summary report books for action by TAC
June-July (X+1)	TAC	—	Meet and take accreditation action
	TC, ED, CC	ABET	Make final revision of visitation report
July	ABET	Inst	Preliminary notification of accreditation action(s)
July-Aug (X+1)	ABET	Inst	Send accreditation letter and final visitation report
Within 30 days	Inst	ABET	Inst may elect to appeal not-to-accredit action to ABET Board of Directors
Sept 30 (X+1)	ABET	—	Old accreditations expire, new ones take effect

**Or less if necessary to get late reports to ABET by March 15*
***Or less if necessary to get late reports to ABET by May 15*

ABET = Accreditation Board for Engineering and Technology (Baltimore office)

Inst = Institution seeking accreditation or reaccreditation

X = Year of Sept–Dec evaluation visit

X–1 = Year preceding start of visit cycle

X+1 = Year accreditation action is completed

CC = Chair of Technology Accreditation Commission

ED = Editor

PB = Participating Body (ABET member society)

TC = Team chair

TM = Team member

SB = State board of engineering examiners

V = Visit date (last day)

V+20 = 20 days after V date

APPENDIX F

APPENDIX F

RECENT MET FACULTY PROFESSIONAL DEVELOPMENT, CONSULTING AND COMMUNITY SERVICE ACTIVITIES

A. Recent Activities of Charles Drake

1. Professional Development Activities

   - Ferris Faculty Summer Institute, May 13-15, 1997. Participation resulted in a $1000 grant to the MET program.
   - Micromeasurements, Inc., Seminar on Stress Analysis. Raleigh, NC, July 14-18, 1997.
   - Ferris Structured Learning Assistance Workshop, August 8, 1997.

2. Committee Assignments

   - Chair, DMGA Department Curriculum Committee, since Fall 1996.
   - Member, University Faculty Athletic Advisory Committee, since Fall 1996

3. Community Service Activities

   - Monday Night Technology: Introduction to engineering and science. This is an enrichment program for middle school students co-sponsored by the Math-Science Center of the Intermediate School district and by Ferris.

   - Team Leader, Science Olympiad, Big Rapids Public Schools. This is a program for middle and high school students.

4. Faculty Advisor for META, the MET student association.

5. Leader in the MET program TAC of ABET accreditation effort.

B. Recent Activities of George Olsson

1. Academic Senate

   Professor Olsson has represented the College of Technology on the Academic Senate since October 1996. In April 1997, he was elected to a two-year term.

2. NCA Steering Committee

   Professor Olsson has been a member of the NCA Steering Committee since April 1996.

3. Clients for recent Consulting Activities

   Amerikam, Inc., April 1997.
   Contact: Robert S. Creswell, Chairman

   The Knowledge Company, March and September 1997.
   Contact: Irving J. Spitzberg, President and Counsel

4. Leader in the MET program TAC of ABET accreditation effort. Gathered data, wrote, edited and organized the publication of the reports submitted to ABET (see attachments 1-3)

APPENDIX G

May 23, 1996

«first_name» «last_name»
«address»
«city_state_zip»

Dear «first_name»,

We urgently need your help. Our Mechanical Engineering Technology program is being reviewed for accreditation by ABET (Accreditation Board for Engineering and Technology). This process requires your input.

Please complete one of the enclosed forms - post card or FAX form - your choice, and return as soon as you can. Your prompt response is very much appreciated. Thanks for your help.

Very truly yours,

Charles G. Drake , P.E.
Assistant Professor

George Olsson, Ph.D.
Professor

Enclosures: Post card
FAX form

MECHANICAL ENGINEERING TECHNOLOGY - ALUMNI SURVEY

Name______________________________**MET/AASYear**___

Address Correction (city state zip)____________________

____

Home Phone______________**Work Phone**_______________

Company Name___________________________________

Position Title____________________________________

Company Address_________________________________

____

E-mail address___________________________________

OPTIONAL INFORMATION: SALARY RANGE FOR CURRENT POSITION

below $30k___$30-35k___$36-40k___$46-50k___above 50k___

YOUR EDUCATION SINCE MET/AAS

College/University_______________Degree______Year___

College/University_______________Degree______Year___

SEMINARS/COURSES (list most recent)

Location________________Topic___________________

Location________________Topic___________________

CAREER AVENUES

Check which category best fits your current position

Design___Testing___Manufacturing___R&D___Sales___Other___

Relevant Scientific and Technical Topics for your Career

Mark as follows: 1 = Very Important, 2 = Necessary, 3 = Unimportant

___Mathematics
___Physics
___Drafting
___CAD
___Mfg. Processes
___Computer Programming
___Electronic Spreadsheets
___Application Software
___Statics & Strength of Materials
___Pneumatics & Hydraulics
___Fluid Mechanics
___Kinematics
___Machine Design
___Thermodynamics & Heat Transfer
___Mechanical Measurements & Instrumentation
___Electricity & Electronics
___Material Science /Metallurgy

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS MAIL PERMIT NO. 8 BIG RAPIDS, MI

POSTAGE WILL BE PAID BY ADDRESSEE

Attn: Chuck Drake
Manufacturing Engineering Technologies Department
Swan 109 (2-39000)
FERRIS STATE UNIVERSITY
111 W KNOLLVIEW DR.
BIG RAPIDS MI 49307-9964

APPENDIX H

APPENDIX H

INDUSTRY SURVEY -- 1996

Company Name:

Company Address:

Kind of Business:

Contact Person:

Phone No./FAX:

HRD (Personnel) Contact:

Phone No./FAX:

1. *How many Ferris Grads do you employ?* (rough estimate)

2. *What percentage have the skills you require?* (rough estimate)

3. *What improvements are needed in the preparation (undergraduate education) of that group?*

4. *Would you consider hiring a Ferris graduate again in the future?*

1996 INDUSTRY SURVEY PARTICIPATING COMPANIES

Cimatron Technology	Plymouth, Michigan
Contech-Alma	Alma, Michigan
Conveyor Components/Cotterman Ladder	Croswell, Michigan
Diversco Construction	Grand Rapids, Michigan
Great Lakes Feedscrews	Tecumseh, Michigan
Hoskins Manufacturing Company	Mio, Michigan
Howmet Industries	Whitehall, Michigan
Huron Plastics Group	Port Huron, Michigan
Kysor of Cadillac	Cadillac, Michigan
Means Industries	Vassar, Michigan
Miller Bros. Manufacturing	Homer, Michigan
Paulstra Corporation	Grand Rapids, Michigan
Prince Corporation	Holland, Michigan
Quincy, L.P.	Jonesville, Michigan
Rapistan Demag	Grand Rapids, Michigan

APPENDIX I

APPENDIX I

MET PROGRAM SELF-STUDY FOR ACADEMIC PROGRAM REVIEW

SURVEY OF INCOMING FIRST YEAR STUDENTS
FALL 1997

PLEASE PRINT ALL CAPS

1. Name: ______________________________ 2. Age: _________ 3. Sex: M F

4. High School: ____________________________ City/town: ___________________________

Year Graduated: _____________

5. Transfer Student: Yes No (If so) Where from? ________________________________

6. Who/what helped you decide to come to Ferris (check all applicable):

_____ Counselor
_____ Teacher
_____ Advertisements
_____ Parents
_____ Friends
_____ Other (Explain): ____________________________
____
_____ Other relatives
_____ Co-workers on job

7. Who/what helped you decide to enroll in the MET program (check all applicable):

_____ Counselor
_____ Teacher
_____ Advertisements
_____ Parents
_____ Friends
_____ Other (Explain): ____________________________
____
_____ Other relatives
_____ Coworkers on job

8. Your impression of the Application/Admissions/Financial Aid/Registration process:

_____ Very favorable
_____ Unfavorable
_____ Favorable
_____ Very unfavorable
_____ Neutral

Comments: ____

9. Your first impression of the College of Technology/MET program/MET faculty

Comments: ____

MET PROGRAM SELF-STUDY FOR ACADEMIC PROGRAM REVIEW

SURVEY OF INCOMING FIRST YEAR STUDENTS
FALL 1997

PLEASE PRINT ALL CAPS

Name: ______________________________

11. What are your plans after completing your AAS MET degree?

_____ Go to work

_____ Go to work and attend school part time

_____ Stay in school and enter a BS degree program

    _____ At Ferris

        _____ BS Product Design Engineering Technology

        _____ BS Manufacturing Engineering Technology

        _____ BS Plastics Engineering Technology

        _____ Other BS program: ______________________________________

    _____ Transfer to another university (describe):

    ____

_____ Don't know.

MET PROGRAM SELF-STUDY FOR ACADEMIC PROGRAM REVIEW

SURVEY OF SECOND YEAR STUDENTS
FALL 1997

PLEASE PRINT ALL CAPS

1. Name: ______________________________ 2. Age: _________ 3. Sex: M F

4. High School: ____________________________ City/town: ___________________________

Year Graduated: _____________

5. Transfer Student: Yes No (If so) Where from? ________________________________

6. Who/what helped you decide to come to Ferris (check all applicable):

_____ Counselor
_____ Teacher
_____ Advertisements
_____ Parents
_____ Friends
_____ Other (Explain): ____________________________
____
_____ Other relatives
_____ Co-workers on job

7. Who/what helped you decide to enroll in the MET program (check all applicable):

_____ Counselor
_____ Teacher
_____ Advertisements
_____ Parents
_____ Friends
_____ Other (Explain): ____________________________
____
_____ Other relatives
_____ Coworkers on job

8. Your impression of the Application/Admissions/Financial Aid/Registration process:

_____ Very favorable
_____ Unfavorable
_____ Favorable
_____ Very unfavorable
_____ Neutral

Comments: ____

____

____

SURVEY OF SECOND YEAR STUDENTS
FALL 1997

PLEASE PRINT ALL CAPS

Name: ______________________________

9. Your impression of the MET program faculty:

_____ Very favorable _____ Favorable _____ Neutral

_____ Unfavorable _____ Very unfavorable

Comments: ____

____

____

10. What is your impression of the laboratory facilities and equipment for your first year courses (MFGT 150 Manufacturing Processes and PHYS 211 Introduction to Physics)?

_____ Very favorable _____ Favorable _____ Neutral

_____ Unfavorable _____ Very unfavorable

Comments: ____

____

____

11. What is your impression so far of the mechanical engineering technology program course of study?

_____ Very favorable _____ Favorable _____ Neutral

_____ Unfavorable _____ Very unfavorable

Comments: ____

____

____

SURVEY OF SECOND YEAR STUDENTS
FALL 1997

PLEASE PRINT ALL CAPS

Name: ____________________________

12. What are your plans after completing your AAS MET degree?

_____ Go to work

_____ Go to work and attend school part time

_____ Stay in school and enter a BS degree program

    _____ At Ferris

        _____ BS Product Design Engineering Technology

        _____ BS Manufacturing Engineering Technology

        _____ BS Plastics Engineering Technology

        _____ Other BS program: ____________________________________

    _____ Transfer to another university (describe):

        ____

_____ Don't know.

GRADUATE SURVEY – SECOND YEAR STUDENTS – MAY 1997

Name: ______________________________

Summer Address: ______________________________

____

Permanent Address: ______________________________

____

Employment Plans: ______________________________

____

____

Plans for further education: ______________________________

____

____

Why did I enter the MET program: ______________________________

____

____

How has the MET program helped me: ______________________________

____

____

Have my expectations of this program been met: ______________________________

____

____

APPENDIX J

RESPONSES TO GRADUATE SURVEY – SECOND YEAR STUDENTS – MAY 1997

A. WHY DID I ENTER THE MET PROGRAM?

- I entered the MET program because I am a math minded individual. I like doing analysis of things, and this was the best program that fit my needs and ambitions.
- I was looking for a program that would give me a good paying job in not a long time period in subjects that I was interested in. I also entered this program because when I was looking for a school to attend, the advisors were very helpful to take time and show me around the campus.
- I entered the MET program because I wanted to get a good paying job in a subject that I am comfortable with. I have always been interested in this program.
- I had always wanted to be an engineer but I heard a lot of great things about the program and that was all that it took for me.
- I chose MET to get in to PDET to design products.
- Ever since I first started on AUTOCAD, I've wanted to draw and design parts. I really didn't know what a mechanical engineer did but the mechanical part pulled me in.
- I felt the MET program was a strong program. Before deciding a career, I went to businesses and shadow probed the prospective jobs that I had in mind. From there, I decided that mechanical engineering was the most interesting choice for me.
- I entered the MET program because I heard that Ferris had a hands-on engineering program. This sounded like it would be more useful to me.
- I simply felt that it might be interesting. It was really something that I, originally, just wanted to "try out."
- I entered the MET program as the beginning of a 2 + 2 engineering program. The associates degree in MET has been a stepping stone to my goal of achieving a manufacturing engineering technology degree.
- Honestly, I entered the MET program here at FSU because it was relative close to home and the program seemed to be one of the best that I have seen. My other option was to take the same program at LSSU.
- I entered this program because I knew I wanted to do something in the engineering field.
- I had a boss at a machine shop I worked at in high school that was a mechanical engineer, and I liked his job. I attended Ferris because I heard they had a good program.
- I entered it because I wanted to learn more about designing products and how to build them because that is something that has always interested me.
- MET was not my first choice at FSU. After talking with some advisors that are not around anymore, I decided that MET sounded interesting.

B. HOW HAS THE MET PROGRAM HELPED ME?

- Doing well in this program has given me the opportunity to further my career in education and in industry.

- It has put me in a good position to transfer into two different B.S. programs and keep building on my education.

- The MET program has helped me with my career goal by exposing me to the technical things needed for a good job. It has also put me in a position to go on to further education in two other programs, one of which I am going into. The program has enhanced my knowledge much from what it was in high school.

- I believe that the program has well prepared me for the next step in my educational career. The summer job that I have is not one that best suits my educational background, but I am looking for other opportunities for employment.

- MET taught me things I needed to know for the future in industry.

- The MET program gave me confidence to continue on in PDET and taught me the basic concepts of engineering.

- Educational Advancement: I feel that the program has prepared me well for what is ahead of me. I have a good grasp of what is expected of a mechanical engineer.
  Career Guidance, Qualifications and Placement: Before entering the program, my intentions were to continue into the product design program. I believe that the MET program has enhanced my path to a successful career and proved to lead toward a degree in product design.

- The MET program gave me a large base in engineering which will be useful.

- (a) Educational advancement: It's provided me with the fundamental courses and skills to move onto more specific/advanced education.
  (b) Career guidance, qualification, and placement: Taking the courses has brought me to the decision that mechanical engineering is where some of my greatest interest and abilities are. It's provided me with courses that are preferred by the majority of employers in this field.
  (c) Placement: Due to the courses provided, I've become a candidate for a large number of employers.

- The program has provided the information and developed the skills necessary to move on in my education and eventually pursue a career in the manufacturing engineering field.

- A. The MET program gave me a good background for the degree in PDET which I wish to achieve.
  B. My career goals are to get myself out in the design field in industry.

- This program helped me gain great knowledge in the field of engineering. It helped me get accepted to the product design program. I also gained enough knowledge to be prepared for the product design program. Finally, it helped me get a job in the summer because of its reputation.

- (a) Educational Advancement: It helped me advance to the product design program at Ferris.
  (b) Career Guidelines, Qualifications, and Placement: The program has helped me to get a degree, which interning should help me to get a job as an engineer after graduation.

- Educational advancement: It has given me the ability to be competitive in the job market if I were to get a job right now.

- Preparing myself to enter into an engineering program B.A. or M.A.

C. HAVE MY EXPECTATIONS FOR THIS PROGRAM BEEN MET?

- My expectations of this program have been more than exceeded. I am very pleased with the education I have received.

- Yes, I am very happy and excited to be completing my degree. It has been a good experience for me and [I] would recommend it to my friends.

- Yes, my expectations have been met for the MET program.

- Due to all the courses that are in the program, it has surpassed my first thoughts of the program.

- I was expecting more drafting in MET.

- I would have to say that this program went above and beyond my expectations. I didn't know the slightest thing about fluids, kinematics, statics, thermal, or machine design but know I feel that I have a working understanding of all of them.

- I believe that my expectations for the most part have been met. I would have liked to have more lab time to experiment in all the course classes but know that this is not possible. I feel the knowledge learned for experience is incomparable.

- Yes. I learned a lot of new information which I'm sure will be useful in the future.

- Yes. Due to the workload of the courses, I don't believe that I could have learned anymore without risking my health. The only suggestion that I could make is to decrease the traditional drafting section in order to place more emphasis on the computer-aided drafting.

- I feel that the program has provided a well rounded, practical curriculum that will be very useful. I hoped to achieve a high level of education and this program has provided it.

- Yes, I would say that my expectations were met in regards to the subject material in my courses. I strongly suggest that the QBASIC portion of the MET program should be taken seriously and taught by a decent teacher. Needless to say, the instructor I had wasn't a teacher. This very treatment makes me feel like Ferris isn't a top- notch college. Also, some money needs to be spent on lab equipment for the progran!

- Most of my expectations in this course were met.

- Yes, the program has been very challenging. It has also taught me a lot about the engineering field which will be helpful in future employment.

- Yes, I am able to design basic things and decide on how to get them made which is what I wanted from the program.

- Yes. Stats and strenghts should return to a double class with part 1 and part 2 separate terms. Also, there should be a computer class that deals with Microsoft Office.

APPENDIX K

1

COLLEGE TECHNOLOGY

FACULTY PERCEPTIONS OF OCCUPATIONAL EDUCATION PROGRAMS

INSTRUCTIONS TO RESPONDENTS

On the following pages you are asked to give your perceptions of your occupational program (such as registered nursing, automotive technology, secretarial science). The items you are asked to rate are grouped into the major components of the Program Review in Occupational Education (PROE) system, namely:

- Goals and Objectives
- Processes
- Resources

Rate each item by checking your best judgment on a five point scale ranging from poor to excellent. Only check one answer per item. A "Don't Know" column has been provided in the event you really don't have sufficient information to rate an item. Space has been provided for you to note comments that may help to clarify your ratings or to indicate modifications of a standard to make it more relevant for your program.

Criteria for excellent and poor ratings are provided for each item. *Excellent* represents a nearly ideal or exemplary situation; *poor,* one of serious inadequacy. As a guide, ratings may be made with the following in mind:

EXCELLENT means ideal, top 5 to 10%
GOOD is a strong rating, top 1/3rd
ACCEPTABLE is average, the middle 1/3rd
BELOW EXPECTATIONS is only fair, bottom 1/3rd
POOR is seriously inadequate, bottom 5 to 10%

This form may be completed as a *consensus* evaluation by the principal persons involved with a specific occupational program. Examples of such persons would be instructors, department or division chairpersons, program coordinators, and administrators such as occupational dean. If preferred, respondents may complete individual forms.

To help with tabulation of responses, please provide the information requested below before completing your rating.

PROGRAM TITLE MECHANICAL ENGINEERING TECHNOLOGY USOE CODE # __ __.__ __ __ __ __ __

PERSONS PARTICIPATING IN CONSENSUS EVALUATION OR INDIVIDUAL COMPLETING THIS FORM:

Name	Title
CHARLES DRAKE	ASSOCIATE PROFESSOR
GEORGE OLSSON	PROFESSOR

Thanks for your cooperation!

PROE

1

FACULTY PERCEPTIONS OF OCCUPATIONAL EDUCATION PROGRAMS

GOALS AND OBJECTIVES

	Keypunch Instructions	1 Poor	2 Below Expectations	3 Acceptable	4 Good	5 Excellent	Don't Know	COMMENTS (Please note explanatory remarks or needs for improvement)
1. Participation in Development of College Occupational Education Program Plan *Excellent*—Administrators and/or other supervisory personnel involved in developing and revising the college plan for this occupational program seek and respond to faculty, student and community input. *Poor*—Development of the plan for this program is basically the work of one or two persons in the college.	1				✓			
2. Program Goals *Excellent*—Written goals for this program state realistic outcomes (such as planned enrollments, completions, placements) and are used as one measure of program effectiveness. *Poor*—No written goals exist for this program.	2				✓			
3. Course Objectives *Excellent*—Written measurable objectives have been developed for all occupational courses in this program and are used to plan and organize instruction. *Poor*—No written objectives have been developed for courses in this program.	3					✓	≠	
4. Competency Based Performance Objectives *Excellent*—Competency based performance objectives are on file in writing, consistent with employment standards, and tell students what to expect and help faculty pace instruction. *Poor*—Competency based performance objectives have not been developed for courses in this program.	4				✓			
5. Use of Competency Based Performance Objectives *Excellent*—Competency based performance objectives are distributed to students and used to assess student progress. *Poor*—Competency based performance objectives are not used with students for progress evaluation nor are students aware that they exist.	5				✓			
6. Use of Information on Labor Market Needs *Excellent*—Current data on labor market needs and emerging trends in job openings are systematically used in developing and evaluating this program. *Poor*—Labor market data is not used in planning or evaluation.	6					✓		
7. Use of Information on Job Performance Requirements *Excellent*—Current data on job performance requirements and trends are systematically used in developing and evaluating this program and content of its courses. *Poor*—Job performance requirements information has not been collected for use in planning and evaluating.	7					✓		

PROE

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FACULTY PERCEPTIONS OF OCCUPATIONAL EDUCATION PROGRAMS

	Keypunch Instructions	Poor 1	Below Expectations 2	Acceptable 3	Good 4	Excellent 5	Don't Know	COMMENTS (Please note explanatory remarks or needs for improvement)
GOALS AND OBJECTIVES (Continued)								
8. Use of Profession/Industry Standards *Excellent*—Profession/industry standards (such as licensing, certification, accreditation) are consistently used in planning and evaluating this program and content of its courses. *Poor*—Little or no recognition is given to specific profession/industry standards in planning and evaluating this program.	8					✓		
9. Use of Student Follow-Up Information *Excellent*—Current follow-up data on completers and leavers (students with marketable skills) are consistently and systematically used in evaluating this program. *Poor*—Student follow-up information has not been collected for use in evaluating this program.	9				✓			
PROCESSES								
10. Adaptation of Instruction *Excellent*—Instruction in all courses required for this program recognizes and responds to individual student interests, learning styles, skills, and abilities through a variety of instructional methods (such as small group or individualized instruction, laboratory or "hands on" experiences, open entry/open exit, credit by examination). *Poor*—Instructional approaches in this program do not consider individual student differences.	10					✓		
11. Relevance of Supportive Courses *Excellent*—Applicable supportive courses (such as anatomy and physiology, technical communications, technical mathematics) are closely coordinated with this program and are kept relevant to program goals and current to the needs of students. *Poor*—Supportive course content reflects no planned approach to meeting needs of students in this program.	11					✓		
12. Coordination with Other Community Agencies and Educational Programs. *Excellent*—Effective liaison is maintained with other programs and educational agencies and institutions (such as high schools, other community colleges, four year colleges, area vocational schools, proprietary schools, CETA) to assure a coordinated approach and to avoid duplication in meeting occupational needs of the area or community. *Poor*—College activities reflect a disinterest in coordination with other programs and agencies having impact on this program.	12				✓			
13. Provision for Work Experience, Cooperative Education or Clinical Experience. *Excellent*—Ample opportunities are provided for related work experience, cooperative education, or clinical experience for students in this program. Student participation is well coordinated with classroom instruction and employer supervision. *Poor*—Few opportunities are provided in this program for related work experience, cooperative education, or clinical experience where such participation is feasible.	13				✓			

PRUE

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FACULTY PERCEPTIONS OF OCCUPATIONAL EDUCATION PROGRAMS

PROCESSES (Continued)

	Keypunch Instructions	Poor 1	Below Expectations 2	Acceptable 3	Good 4	Excellent 5	Don't Know	COMMENTS (Please note explanatory remarks or needs for improvement)
14. Program Availability and Accessibility *Excellent*—Students and potential students desiring enrollment in this program are identified through recruitment activities, treated equally in enrollment selection, and not discouraged by unrealistic prerequisites. The program is readily available and accessible at convenient times and locations. *Poor*—This program is not available or accessible to most students seeking enrollment. Discriminatory selection procedures are practiced.	14					✓		
15. Provision for the Disadvantaged *Excellent*—Support services are provided for disadvantaged (such as socioeconomic, cultural, linguistic, academic) students enrolled in this program. Services are coordinated with occupational instruction and results are assessed continuously. *Poor*—No support services are provided for disadvantaged students enrolled in this program.	15				✓			
16. Provision for the Handicapped. *Excellent*—Support services are provided for handicapped (physical, mental, emotional, and other health impairing handicaps) students enrolled in this program. Facilities and equipment adaptations are made as needed. Services and facilities modifications are coordinated with occupational instruction and results are assessed continuously. *Poor*—No support services or facilities and equipment modifications are available for handicapped students enrolled in this program.	16				✓			
17. Efforts to Achieve Sex Equity *Excellent*—Emphasis is given to eliminating sex bias and sex stereotyping in this program: staffing, student recruitment, program advisement, and career counseling; access to and acceptance in programs; selection of curricular materials; instruction; job development and placement. *Poor*—Almost no attention is directed toward achieving sex equity in this program.	17					✓		
18. Provision for Program Advisement *Excellent*—Instructors or other qualified personnel advise students (day, evening, weekend) on program and course selection. Registration procedures facilitate course selection and sequencing. *Poor*—Instructors make no provision for advising students on course and program selection.	18					✓		
19. Provision for Career Planning and Guidance *Excellent*—Day, evening, and weekend students in this program have ready access to career planning and guidance services. *Poor*—Little or no provision is made for career planning and guidance services for students enrolled in this program.	19					✓		

PROE

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FACULTY PERCEPTIONS OF OCCUPATIONAL EDUCATION PROGRAMS

	Keypunch Instructions	Poor 1	Below Expectations 2	Acceptable 3	Good 4	Excellent 5	Don't Know	COMMENTS (Please note explanatory remarks or needs for improvement)
PROCESSES (Continued)								
20. Adequacy of Career Planning and Guidance *Excellent*—Instructors or other qualified personnel providing career planning and guidance services have current and relevant occupational knowledge and use a variety of resources (such as printed materials, audiovisuals, job observation) to meet individual student career objectives. *Poor*—Career planning and guidance services are ineffective and staffed with personnel who have little occupational knowledge.	20					✓		
21. Provision for Employability Information. *Excellent*—This program includes information which is valuable to students as employees (on such topics as employment opportunities and future potential, starting salary, benefits, responsibilities and rights). *Poor*—Almost no emphasis is placed on providing information important to students as employees.	21					✓		
22. Placement Effectiveness for Students in this Program *Excellent*—The college has an effectively functioning system for locating jobs and coordinating placement for students in this program. *Poor*—The college has no system or an ineffective system for locating jobs and coordinating placement for occupational students enrolled in this program.	22					✓		
23. Student Follow-up System *Excellent*—Success and failure of program leavers and completers are assessed through periodic follow-up studies. Information learned is made available to instructors, students, advisory committee members and others concerned (such as counselors) and is used to modify this program. *Poor*—No effort is made to follow up former students of this program.	23					✓		
24. Promotion of this Occupational Program *Excellent*—An active and organized effort is made to inform the public and its representatives (such as news media, legislators, board, business community) of the importance of providing effective and comprehensive occupational education and specific training for this occupation to gain community support. *Poor*—There is no organized public information effort for this program.	24				✓			
RESOURCES								
25. Provision for Leadership and Coordination *Excellent*—Responsibility, authority, and accountability for this program are clearly identified and assigned. Administrative effectiveness is achieved in planning, managing, and evaluating this program. *Poor*—There are no clearly defined lines of responsibility, authority, and accountability for this program.	25				✓			

FACULTY PERCEPTIONS OF OCCUPATIONAL EDUCATION PROGRAMS

RESOURCES (Continued)

	Keypunch Instructions	Poor 1	Below Expectations 2	Acceptable 3	Good 4	Excellent 5	Don't Know	COMMENTS (Please note explanatory remarks or needs for improvement)
26. Qualifications of Administrators and/or Supervisors *Excellent*—All persons responsible for directing and coordinating this program demonstrate a high level of administrative ability. They are knowledgeable in and committed to occupational education. *Poor*—Persons responsible for directing and coordinating this program have little administrative training, education, and experience.	26				✓			
27. Instructional Staffing *Excellent*—Instructional staffing for this program is sufficient to permit optimum program effectiveness (such as through enabling instructors to meet individual student needs, providing liaison with advisory committees, and assisting with placement and follow-up activities). *Poor*—Staffing is inadequate to meet the needs of this program effectively.	27					✓		
28. Qualifications of Instructional Staff *Excellent*—Instructors in this program have two or more years in relevant employment experience, have kept current in their field, and have developed and maintained a high level of teaching competence. *Poor*—Few instructors in this program have relevant employment experience or current competence in their field.	28					✓		
29. Professional Development Opportunities *Excellent*—The college encourages and supports the continuing professional development of faculty through such opportunities as conference attendance, curriculum development, work experience. *Poor*—The college does not encourage or support professional development of faculty.	29					✓		
30. Use of Instructional Support Staff *Excellent*—Paraprofessionals (such as aides, laboratory assistants) are used when appropriate to provide classroom help to students and to ensure maximum effectiveness of instructors in the program. *Poor*—Little use is made of instructional support staff in this program.	30					✓		
31. Use of Clerical Support Staff *Excellent*—Office and clerical assistance is available to instructors in this program and used to ensure maximum effectiveness of instructors. *Poor*—Little or no office and clerical assistance is available to instructors; ineffective use is made of clerical support staff.	31					✓		
32. Adequacy and Availability of Instructional Equipment. *Excellent*—Equipment used on or off campus for this program is current, representative of that used on jobs for which students are being trained, and in sufficient supply to meet the needs of students. *Poor*—Equipment for this program is outmoded and in insufficient quantity to support quality instruction.	32				✓			

PROE 1

FACULTY PERCEPTIONS OF OCCUPATIONAL EDUCATION PROGRAMS

RESOURCES (Continued)	Keypunch Instructions	Poor 1	Below Expectations 2	Acceptable 3	Good 4	Excellent 5	Don't Know	COMMENTS (Please note explanatory remarks or needs for improvement)
33. Maintenance and Safety of Instructional Equipment *Excellent*—Equipment used for this program is operational, safe, and well maintained. *Poor*—Equipment used for this program is often not operable and is unsafe.	33				✓			
34. Adequacy of Instructional Facilities *Excellent*—Instructional facilities (excluding equipment) meet the program objectives and student needs, are functional and provide maximum flexibility and safe working conditions. *Poor*—Facilities for this program generally are restrictive, disfunctional, or overcrowded.	34					✓		
35. Scheduling of Instructional Facilities *Excellent*—Scheduling of facilities and equipment for this program is planned to maximize use and be consistent with quality instruction. *Poor*—Facilities and equipment for this program are significantly under- or over-scheduled.	35					✓		
36. Adequacy and Availability of Instructional Materials and Supplies *Excellent*—Instructional materials and supplies are readily available and in sufficient quantity to support quality instruction. *Poor*—Materials and supplies in this program are limited in amount, generally outdated, and lack relevance to program and student needs.	36					✓		
37. Adequacy and Availability of Learning Resources *Excellent*—Learning resources for this program are available and accessible to students, current and relevant to the occupation, and selected to avoid sex bias and stereotyping. *Poor*—Learning resources for this program are outdated, limited in quantity, and lack relevance to the occupation.	37					✓		
38. Use of Advisory Committees *Excellent*—The advisory committee for this program is active and representative of the occupation. *Poor*—The advisory committee for this program is not representative of the occupation and rarely meets.	38					✓		
39. Provisions in Current Operating Budget *Excellent*—Adequate funds are allocated in the college operating budget to support achievement of approved program objectives. Allocations are planned to consider instructor budget input. *Poor*—Funds provided are seriously inadequate in relation to approved objectives for this program.	39				✓			
40. Provisions in Capital Outlay Budget for Equipment *Excellent*—Funds are allocated in a planned effort to provide for needed new equipment and for equipment replacement and repair, consistent with the objectives for this program and based on instructor input. *Poor*—Equipment needs in this program are almost totally unmet in the capital outlay budget.	40			✓				There exist no regular Repair & Replacement or Capital Equipmen budgets...! Only Voc Ed Funding.

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PROE

FACULTY PERCEPTIONS OF OCCUPATIONAL EDUCATION PROGRAMS

Please answer the following: (Use back of page and extra sheets if necessary).

1. What are the chief occupational education strengths of your program?

[See Section 5]

2. What are the major needs for improvement in your program and what action is required to achieve these improvements?

[See Section 5]

PLEASE IDENTIFY THE POSITION OF THE PERSON COMPLETING THIS FORM AND THE OCCUPATIONAL PROGRAM (such as registered nursing, data processing).

Check One:
Division/Department Chair ____
Faculty (2) ✓
Counselor ____
Other, please specify: ____ ________

Program: MECHANICAL ENGINEERING TECHNOLOGY

APPENDIX L

Mechanical Engineering Technology Advisory List

Revised 3/26/97

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APPENDIX M

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INDUSTRY ADVISORY BOARD SURVEY FOR ACADEMIC PROGRAM REVIEW

MECHANICAL ENGINEERING TECHNOLOGY
ASSOCIATE IN APPLIED SCIENCE DEGREE PROGRAM
AUGUST 1997

Premise	Strongly Agree	Agree	Disagree	Strongly Disagree
1. The MET AAS Program provides education and training essential to many Michigan industries				
2. The Program provides skills useful to your company				
3. Your company would hire an MET program graduate				
4. The Program curriculum is appropriate to industry needs				
5. Laboratory facilities meet program needs				
6. Program faculty have adequate academic credentials and industrial experience				

COMMENTS:

APPENDIX N

Mechanical Engineers - Nature of the Work

In general, engineers apply the theories and principles of science and mathematics to the economical solution of practical technical problems. Usually their work is the link between a scientific discovery and its commercial application. Engineers design machinery, products, systems, and processes for efficient and economical performance. They design industrial machinery and equipment for manufacturing defense-related goods and weapons systems for the Armed Forces. They design, plan, and supervise the construction of buildings, highways, and rapid transit systems. They also design and develop systems for control and automation of manufacturing, business, and management processes.

Engineers consider many factors in developing a new product. For example, in developing an industrial robot, they determine precisely what function it needs to perform; design and test components; fit them together in an integrated plan; and evaluate the design's overall effectiveness, cost, reliability, and safety. This process applies to products as different as chemicals, computers, gas turbines, helicopters, and toys.

In addition to design and development, many engineers work in testing, production, or maintenance. They supervise production in factories, determine the causes of breakdowns, and test manufactured products to maintain quality. They also estimate the time and cost to complete projects. Some work in engineering management or in sales, where an engineering background enables them to discuss the technical aspects of a product and assist in planning its installation or use.

Most engineers specialize; more than 25 major specialties are recognized by professional societies, and within the major branches are numerous subdivisions. Structural, environmental, and transportation engineering, for example, are subdivisions of civil engineering. Engineers also may specialize in one industry, such as motor vehicles, or in one field of technology, such as propulsion or guidance systems.

This section, which contains an overall discussion of engineering, is preceded separate sections on 10 engineering branches: Aerospace; chemical; civil; electrical and electronics; industrial; mechanical; metallurgical, ceramic, and materials; mining; nuclear; and petroleum engineering. Branches of engineering not covered in detail here, but in which there are established college programs include: Architectural engineering-the design of a building's internal support structure; biomedical engineering-the application of engineering to medical and physiological problems; environmental engineering-a growing discipline involved with identifying, solving, and alleviating environmental problems; and marine engineering-the design and installation of ship machinery and propulsion systems. Engineers in each branch have knowledge and training that can be applied to many fields. Electrical and electronics engineers, for example, work in the medical, computer, missile guidance, and power distribution fields. Because there are many separate problems to solve in a large engineering project, engineers in one field often work closely with specialists in other scientific, engineering, and business occupations.

Engineers often use computers to simulate and test how a machine, structure, or system operates. Many engineers also use computer-aided design systems to produce and analyze designs. They spend a great deal of time writing reports and consulting with other engineers, as complex projects often require an interdisciplinary team of engineers. Supervisory engineers are responsible for major components or entire projects.

Mechanical engineers plan and design tools, engines, machines, and other mechanical equipment. They design and develop power-producing machines such as internal combustion engines, steam and gas turbines, and jet and rocket engines. They also design and develop power-using machines such as refrigeration and air-conditioning equipment, robots, machine tools, materials handling systems, and industrial production equipment.

The work of mechanical engineers varies by industry and function. Specialties include, among others, applied mechanics, design engineering, heat transfer, power plant engineering, pressure vessels and piping, and underwater technology. Mechanical engineers design tools needed by other engineers for their work. Mechanical engineering is the broadest engineering discipline, extending across many interdependent specialties. Mechanical engineers may work in production operations, maintenance, or technical sales. Many are administrators or managers.

Mechanical Engineers - Working Conditions

Many engineers work in laboratories, industrial plants, or at construction sites, where they inspect, supervise, or solve onsite problems. Others work in offices almost all of the time. Engineers in branches such as civil engineering may work outdoors part of the time. A few engineers travel extensively to plants or construction sites.

Many engineers work a standard 40-hour week. At times, deadlines or design standards may bring extra pressure to a job. Wher this happens, engineers may work long hours and experience considerable stress.

Mechanical Engineers - Employment

In 1994, engineers held 1,327,000 jobs.

Forty- seven percent of all engineering jobs were located in manufacturing industries-mostly in electrical and electronic equipment, industrial machinery, scientific instruments, aircraft and parts, motor vehicles, chemicals, guided missiles and space vehicles, fabricated metal products, and primary metals industries. In 1994, 684,000 jobs were in nonmanufacturing industries, primarily in engineering and architectural services, research and testing services, and business services, where firms designed construction projects or did other engineering work on a contract basis for organizations in other parts of the economy. Engineers also worked in the communications, utilities, and construction industries.

Federal, State, and local governments employed about 181,000 engineers. Over half of these were in the Federal Government, mainly in the Departments of Defense, Transportation, Agriculture, Interior, and Energy, and in the National Aeronautics and Space Administration. Most engineers in State and local government agencies worked in highway and public works departments. Some engineers are self-employed consultants.

Engineers are employed in every State, in small and large cities, and in rural areas. Some branches of engineering are concentrated in particular industries and geographic areas.

Mechanical engineers held about 231,000 jobs in 1994. More than 6 out of 10 jobs were in manufacturing-of these, most were in the machinery, transportation equipment, electrical equipment, instruments, and fabricated metal products industries. Business and engineering consulting services and government agencies provided most of the remaining jobs.

Mechanical Engineers - Training, Other Qualifications, and Advancement

A bachelor's degree in engineering from an accredited engineering program is usually required for beginning engineering jobs. College graduates with a degree in a physical science or mathematics may occasionally qualify for some engineering jobs, especially in engineering specialties in high demand. Most engineering degrees are granted in branches such as electrical, mechanical, or civil engineering. However, engineers trained in one branch may work in another. This flexibility allows employers to meet staffing needs in new technologies and specialties where engineers are in short supply. It also allows engineers to shift t fields with better employment prospects, or to ones that match their interests more closely.

In addition to the standard engineering degree, many colleges offer degrees in engineering technology, which are offered as either 2- or 4-year programs. These programs prepare students for practical design and production work rather than for jobs that require more theoretical, scientific and mathematical knowledge. Graduates of 4-year technology programs may get jobs similar to those obtained by graduates with a bachelor's degree in engineering. Some employers regard them as having skills between those of a technician and an engineer.

Graduate training is essential for engineering faculty positions but is not required for the majority of entry-level engineering jobs. Many engineers obtain graduate degrees in engineering or business administration to learn new technology, broaden their education, and enhance promotion opportunities; others obtain law degrees and become attorneys. Many high-level executives in government and industry began their careers as engineers.

About 340 colleges and universities offer a bachelor's degree in engineering, and nearly 300 colleges offer a bachelor's degree in engineering technology, although not all are accredited programs. Although most institutions offer programs in the larger branches of engineering, only a few offer some of the smaller specialties. Also, programs of the same title may vary in content. For example, some emphasize industrial practices, preparing students for a job in industry, while others are more theoretical and are better for students preparing to take graduate work. Therefore, students should investigate curricula and check accreditations carefully before selecting a college. Admissions requirements for undergraduate engineering schools include courses in advanced high school mathematics and the physical sciences.

Bachelor's degree programs in engineering are typically designed to last 4 years, but many students find that it takes between 4 and 5 years to complete their studies. In a typical 4-year college curriculum, the first 2 years are spent studying basic sciences (mathematics, physics, and chemistry), introductory engineering, and the humanities, social sciences, and English. In the last 2 years, most courses are in engineering, usually with a concentration in one branch. For example, the last 2 years of an aerospace program might include courses such as fluid mechanics, heat transfer, applied aerodynamics, analytical mechanics, flight vehicle design, trajectory dynamics, and aerospace propulsion systems. Some programs offer a general engineering curriculum; students then specialize in graduate school or on the job.

A few engineering schools and 2-year colleges have agreements whereby the 2-year college provides the initial engineering education and the engineering school automatically admits students for their last 2 years. In addition, a few engineering schools have arrangements whereby a student spends 3 years in a liberal arts college studying preengineering subjects and 2 years in the engineering school and receives a bachelor's degree from each. Some colleges and universities offer 5-year master's degree programs. Some 5- or even 6-year cooperative plans combine classroom study and practical work, permitting students to gain valuable experience and finance part of their education.

All 50 States and the District of Columbia require registration for engineers whose work may affect life, health, or property, or who offer their services to the public. In 1994, between 250,000 and 300,000 engineers were registered. Registration generally requires a degree from an engineering program accredited by the Accreditation Board for Engineering and Technology, 4 years of relevant work experience, and passing a State examination. Some States will not register people with degrees in engineering technology. Engineers may be registered in several states.

Beginning engineering graduates usually do routine work under the supervision of experienced engineers and, in larger companies, may also receive formal classroom or seminar-type training. As they gain knowledge and experience, they are assigned more difficult tasks with greater independence to develop designs, solve problems, and make decisions. Engineers may become technical specialists or may supervise a staff or team of engineers and technicians. Some eventually become engineering managers or enter other managerial, management support, or sales jobs.

Engineers should be able to work as part of a team and should be creative, analytical, and detail-oriented. In addition, engineers should be able to communicate well-both orally and in writing.

Mechanical Engineers - Job Outlook

Employment opportunities in engineering are expected to be good through the year 2005 because employment is expected to increase about as fast as the average for all occupations while the number of degrees granted in engineering is expected to remain near present levels through the year 2005. Many of the jobs in engineering are related to national defense. Because defense expenditures have declined, employment growth and job outlook for engineers may not be as strong as in times when defense expenditures were increasing. However, graduating engineers will continue to be in demand for jobs in engineering and other areas, possibly even at the same time other engineers, especially defense industry engineers, are being laid off.

Employers will rely on engineers to further increase productivity as they increase investment in plant and equipment to expand output of goods and services. In addition, competitive pressures and advancing technology will force companies to improve and update product designs more frequently. Finally, more engineers will be needed to improve deteriorating roads, bridges, water and pollution control systems, and other public facilities.

Freshman engineering enrollments began declining in 1983, and the number of bachelor's degrees in engineering began declining in 1987, as shown in chart 2. Although it is difficult to project engineering enrollments, this decline may continue through the late 1990s because the total college-age population is projected to decline. Furthermore, the proportion of students interested in engineering careers has declined as prospects for college graduates in other fields have improved and interest in other programs has increased. Also, engineering schools have restricted enrollments, especially in defense-related fields such as aerospace engineering, to accommodate the reduced opportunities in defense-related industries.

Only a relatively small proportion of engineers leave the profession each year. Despite this, over 70 percent of all job openings will arise from replacement needs. A greater proportion of replacement openings is created by engineers who transfer to management, sales, or other professional specialty occupations than by those who leave the labor force.

Most industries are less likely to lay off engineers than other workers. Many engineers work on long-term research and development projects or in other activities which may continue even during recessions. In industries such as electronics and aerospace, however, large government cutbacks in defense or research and development have resulted in significant layoffs for engineers.

New computer-aided design systems have improved the design process, enabling engineers to produce or modify designs much more rapidly. Engineers now produce and analyze many more design variations before selecting a final one. However, this technology is not expected to limit employment opportunities.

It is important for engineers to continue their education throughout their careers because much of their value to their employer depends on their knowledge of the latest technology. The pace of technological change varies by engineering specialty and industry. Engineers in high-technology areas such as advanced electronics may find that technical knowledge can become obsolete rapidly. Even those who continue their education are vulnerable if the particular technology or product they have specialized in becomes obsolete. Engineers who have not kept current in their field may find themselves passed over for promotions and are vulnerable should layoffs occur. On the other hand, it is often these high-technology areas that offer the greatest challenges, the most interesting work, and the highest salaries. Therefore, the choice of engineering specialty and employer involves an assessment not only of the potential rewards but also of the risk of technological obsolescence.

Employment of **mechanical engineers** is expected to grow about as fast as the average for all occupations through the year 2005. Although overall employment in manufacturing is expected to decline, employment of mechanical engineers in manufacturing should increase as the demand for machinery and machine tools grows and industrial machinery and processes become increasingly complex. Employment of mechanical engineers in other sectors of the economy, such as construction and services, is expected to grow faster than average as firms in these industries learn to apply these engineers' skills.

Job prospects in this field should be favorable through the year 2005. Most of the expected job openings resulting from employment growth and the need to replace those who will leave the occupation should be sufficient to absorb the supply of new graduates and other entrants.

Many mechanical engineering jobs are in defense-related industries. Reductions in defense spending has and may continue to result in layoffs in these industries.

Mechanical Engineers - Earnings

Starting salaries for engineers with the bachelor's degree are significantly higher than starting salaries of bachelor's degree graduates in other fields. According to the National Association of Colleges and Employers, engineering graduates with a bachelor's degree averaged about $34,100 a year in private industry in 1994; those with a master's degree and no experience, $40,200 a year; and those with a Ph.D., $55,300. Starting salaries for those with the bachelor's degree vary by branch, as shown in the following tabulation. Aerospace $30,860 Chemical 39,204 Civil 29,809 Electrical 34,840 Industrial 33,267 Mechanical 35,051 Metallurgical 33,429 Mining 32,638 Nuclear 33,603 Petroleum 38,286

A survey of workplaces in 160 metropolitan areas reported that beginning engineers had median annual earnings of about $33,900 in 1993, with the middle half earning between about $30,900 and $36,900 a year. Experienced midlevel engineers with no supervisory responsibilities had median annual earnings of about $54,400, with the middle half earning between about $49,800 and $59,600 a year. Median annual earnings for engineers at senior managerial levels were about $90,000. Median annual earnings for these and other levels of engineers are shown in the following tabulation.

Engineer I $33,900 Engineer II 38,500 Engineer III 44,800 Engineer IV 54,400 Engineer V 65,400 Engineer VI 78,100 Engineer VII 90,000 Engineer VIII 105,700

Median annual salaries for all engineers was about $46,600 in 1994. Those with a bachelor's degree had median earnings of $47,100; master's degree holders, $53,200; and PhDs, $62,300. Median salaries for some engineering specialties were:

Aerospace $50,200 Chemical 53,100 Civil 44,700 Electrical 48,000 Industrial 40,900 Mechanical 46,400 Engineers, nec 45,400

The average annual salary for engineers in the Federal Government in nonsupervisory, supervisory, and managerial positions was $58,080 in 1995.

Mechanical Engineers - Related Occupations

Engineers apply the principles of physical science and mathematics in their work. Other workers who use scientific and mathematical principles include physical scientists, life scientists, computer scientists, mathematicians, engineering and science technicians, and architects.

Mechanical Engineers - Sources of Additional Information

High school students interested in obtaining general information on a variety of engineering disciplines should contact the Junior Engineering Technical Society by sending a self-addressed business-size envelope with 6 first-class stamps affixed to: JETS-Guidance, at 1420 King St., Suite 405, Alexandria, VA 22314. Non-high school students and those wanting more detailed information should contact societies representing the individual branches of engineering. Each can provide information about careers in the particular branch.

Aeronautical and Aerospace Engineering, send $3 to: American Institute of Aeronautics and Astronautics, Inc., AIAA Student Programs, The Aerospace Center, 370 L'Enfant Promenade SW., Washington, DC 20024-2518.

Chemical Engineering American Institute of Chemical Engineers, 345 East 47th St., New York, NY 10017-2395. American Chemical Society, Career Services, 1155 16th St. NW., Washington, DC 20036.

Civil Engineering American Society of Civil Engineers, 345 E. 47th St., New York, NY 10017.

Electrical and Electronics Engineering Institute of Electrical and Electronics Engineers, 1828 L St. NW., Suite 1202, Washington, DC 20036.

Industrial Engineering Institute of Industrial Engineers, Inc., 25 Technology Park/Atlanta, Norcross, GA 30092.

Mechanical Engineering The American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE., Atlanta, GA 30329.

Metallurgical, Ceramic, and Materials Engineering The Minerals, Metals, & Materials Society, 420 Commonwealth Dr., Warrendale, PA 15086-7514. ASM International, Student Outreach Program, Materials Park, OH 44073-0002.

Mining Engineering The Society for Mining, Metallurgy, and Exploration, Inc., P.O. Box 625002, Littleton, CO 80162-5002.

Nuclear Engineering American Nuclear Society, 555 North Kensington Ave., LaGrange Park, IL 60525.

Petroleum Engineering Society of Petroleum Engineers, 222 Palisades Creek Dr., Richardson, TX 75080.

OPEN OPTIONS -- MICHIGAN TRAINING PROGRAMS

9/10/97

Facility	Program	Address	City, State Zip	Phone	L	Typ	County
ANDREWS UNIVERSITY	MECHANICAL ENGINEERING TECH (BET)	N US HWY 31	BERRIEN SPRINGS, MI 49104	800-253-2874	4	UNI	BERRIEN
GMI ENGINEERING & MANAGEMENT INSTIT	MECHANICAL ENGINEERING	1700 W THIRD AVE	FLINT, MI 48504	810-762-7865	4	COL	GENESEE
LAWRENCE TECHNOLOGICAL UNIVERSITY	MECHANICAL ENGINEERING	21000 W TEN MILE RD	SOUTHFIELD, MI 48075	800-225-5588	4	UNI	OAKLAND
MICHIGAN STATE UNIVERSITY	MECHANICAL ENGINEERING	100 E GRAND RIVER AVE	EAST LANSING, MI 48824	517-355-8332	4	UNI	INGHAM
MICHIGAN STATE UNIVERSITY	MECHANICAL ENGINEERING	100 E GRAND RIVER AVE	EAST LANSING, MI 48824	517-355-8332	6	UNI	INGHAM
MICHIGAN STATE UNIVERSITY	MECHANICAL ENGINEERING	100 E GRAND RIVER AVE	EAST LANSING, MI 48824	517-355-8332	8	UNI	INGHAM
MICHIGAN TECHNOLOGICAL UNIVERSITY	MECHANICAL ENGINEERING	1400 TOWNSEND DRIVE	HOUGHTON, MI 49931	906-487-2335	4	UNI	HOUGHTON
MICHIGAN TECHNOLOGICAL UNIVERSITY	MECHANICAL ENGINEERING	1400 TOWNSEND DRIVE	HOUGHTON, MI 49931	906-487-2335	6	UNI	HOUGHTON
MICHIGAN TECHNOLOGICAL UNIVERSITY	MECHANICAL ENGRG - ENGRG MECH	1400 TOWNSEND DRIVE	HOUGHTON, MI 49931	906-487-2335	8	UNI	HOUGHTON
MOTT COMMUNITY COLLEGE	ASSEMBLY - PRODUCT ENGINEERING*	1401 E COURT ST	FLINT, MI 48502-2394	810-762-0383	0	CC	GENESEE
OAKLAND UNIVERSITY	MECHANICAL ENGINEERING	101 NORTH FOUNDATION HALL	ROCHESTER, MI 48309	810-370-3360	4	UNI	OAKLAND
OAKLAND UNIVERSITY	MECHANICAL ENGINEERING	101 NORTH FOUNDATION HALL	ROCHESTER, MI 48309	810-370-3360	6	UNI	OAKLAND
SAGINAW VALLEY STATE UNIVERSITY	MECHANICAL ENGINEERING	7400 BAY ROAD	UNIVERSITY CENTER, MI 48710	517-790-4200	4	UNI	BAY
UNIVERSITY OF DETROIT MERCY	MECHANICAL ENGINEERING	4001 W MCNICHOLS	DETROIT, MI 48221	313-993-1245	4	UNI	WAYNE
UNIVERSITY OF DETROIT MERCY	MECHANICAL ENGINEERING	4001 W MCNICHOLS	DETROIT, MI 48221	313-993-1245	6	UNI	WAYNE
UNIVERSITY OF DETROIT MERCY	MECHANICAL ENGINEERING	4001 W MCNICHOLS	DETROIT, MI 48221	313-993-1245	8	UNI	WAYNE
UNIVERSITY OF MICHIGAN-ANN ARBOR	MECHANICAL ENGINEERING	1220 STUDENT ACTIVITIES BLDG	ANN ARBOR, MI 48109	313-764-7433	4	UNI	WASHTENAW
UNIVERSITY OF MICHIGAN-ANN ARBOR	MECHANICAL ENGINEERING	1220 STUDENT ACTIVITIES BLDG	ANN ARBOR, MI 48109	313-764-7433	6	UNI	WASHTENAW
UNIVERSITY OF MICHIGAN-ANN ARBOR	MECHANICAL ENGINEER	1220 STUDENT ACTIVITIES BLDG	ANN ARBOR, MI 48109	313-764-7433	7	UNI	WASHTENAW
UNIVERSITY OF MICHIGAN-ANN ARBOR	MECHANICAL ENGINEERING	1220 STUDENT ACTIVITIES BLDG	ANN ARBOR, MI 48109	313-764-7433	8	UNI	WASHTENAW
UNIVERSITY OF MICHIGAN-DEARBOR	MECHANICAL ENGINEERING	4901 EVERGREEN	DEARBORN, MI 48128	313-593-5100	4	UNI	WAYNE
UNIVERSITY OF MICHIGAN-DEARBOR	MECHANICAL ENGINEERING	4901 EVERGREEN	DEARBORN, MI 48128	313-593-5100	6	UNI	WAYNE
WAYNE STATE	MECHANICAL	HELEN NEWBERRY	DETROIT, MI	313-577-3444	4	UNI	WAYNE

OPEN OPTIONS -- MICHIGAN TRAINING PROGRAMS

9/10/97

Facility	Program	Address	City, State Zip	Phone	L	Typ	County
UNIVERSITY	ENGINEERING	JOY STUDENT SVS. CTR	48202				
WAYNE STATE UNIVERSITY	MECHANICAL ENGINEERING	HELEN NEWBERRY JOY STUDENT SVS. CTR	DETROIT, MI 48202	313-577-3444	6	UNI	WAYNE
WAYNE STATE UNIVERSITY	MECHANICAL ENGINEERING	HELEN NEWBERRY JOY STUDENT SVS. CTR	DETROIT, MI 48202	313-577-3444	8	UNI	WAYNE
WESTERN MICHIGAN UNIVERSITY	MECHANICAL ENGINEERING	SEIBERT ADMIN BLDG	KALAMAZOO, MI 49008	616-387-2000	4	UNI	KALAMAZOO
WESTERN MICHIGAN UNIVERSITY	MECHANICAL ENGINEERING	SEIBERT ADMIN BLDG	KALAMAZOO, MI 49008	616-387-2000	6	UNI	KALAMAZOO
WESTERN MICHIGAN UNIVERSITY	MECHANICAL ENGINEERING	SEIBERT ADMIN BLDG	KALAMAZOO, MI 49008	616-387-2000	8	UNI	KALAMAZOO

Mechanical Engineering Technology

Student Projects
1997-1998

Section 1 of 3

The 25th Anniversary Mechanical Engineering Technology Student Projects

MECH 221
Mechanical Measurements with Computer Applications

Ferris State University

Big Rapids, Michigan 49307

May 1, 1997

MECHANICAL ENGINEERING TECHNOLOGY PROGRAM

MECH 221
MECHANICAL MEASUREMENTS WITH COMPUTER APPLICATIONS

25th ANNIVERSARY CLASS

STUDENT PROJECTS

MAY 1997

Students

Christopher Clarke
Alan Cook
Matthew Crosson
Robert Hall
James Harral
Jeffrey Kaiser
Brent Lavigne
Ryan Livingston
Jeremy Moelig
Thomas Morden
Jeffrey O'Neill
Brian Rockhold
Darrell Rodriguez
Jason Roelle
Janet Tichelaar

Faculty

George R. Olsson, Ph.D.
Professor of Mechanical Engineering Technology

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Stress Analysis of a Cantilever Beam for Comparison with Computer Generated Finite Element Analysis

Mech 221
Section 212
Mechanical Measurements with Computer Applications

Mechanical Engineering Technology Program
Ferris State University

April 30, 1997

by
J. M. O'Neill
Jeff Kaiser
Lab Group #5

Mech. 221 Stress Analysis of a Cantilever Beam – Computer FEA Comparison

Summary

The objective of this laboratory project to use strain gages to measure the axial stress field profile in a cantilever beam. The results of this are to be compared with the resulting data from a computer generated finite element analysis of the same apparatus. Thus comparing the theoretical values with the actual experimental values obtained. The relationship of:

$$E = \sigma/\varepsilon$$

will be used to translate the readings of strain indicated at the eight strain gage locations and translate them to stress. From data collected and reduced it was found that at the four points where readings were taken, percent error at each was found to be:

Point A:	0.73 %
Point B:	12.52 %
Point C:	0.79 %
Point D:	7.84 %

This resulted in the following formula for the regression analysis:

Calculated Axial Stress = 33.31 + .935 * *FEA Generated Axial Stress*

This equation is representative of 81.33 % of the data obtained and 18.77 % is represented by scatter about the regression line. Thus, the calculated values of stress at the gage locations was generally comparable to the Algor Finite Element Analysis results.

Mech. 221 Stress Analysis of a Cantilever Beam – Computer FEA Comparison

Contents

Mech. 221 Stress Analysis of a Cantilever Beam – Computer FEA Comparison

I. Objective

The purpose of this laboratory project is to develop a strain profile for an aluminum alloy in bending for comparison with computer simulated results. This will be done by using a cantilever beam setup, with strain gages properly mounted on the beam. Using the strain readings taken from the gage, the data will be reduced and compared to the results of an Algor Finite Element Analysis of the beam. Results will be calculated and compared.

II. Apparatus

The apparatus for this experimental exercise is diagrammed in Figure 1, (below) and consists of the following component parts and materials.

	Count	Device
1.	1	Cantilever flexure frame
2.	1	Aluminum alloy beam, 3 / 16 x 1 x 12 - 1 / 2 inches
3.	1	Strain gage suitable for aluminum (Micro-Measurements CEA-13-240UZ-120)
4.	1	Strain gage application kit and supplies
5.	1	Temperature controlled soldering iron and soldering supplies
6.	1	Protractor
7.	1	Engineering scale
8.	1	Set of precision gram masses
9.	1	Wheatstone bride completion circuit (SB 10)
10.	1	Strain Indicator (P 3500)
11.	1	Computer Finite Element Analysis (Algor)

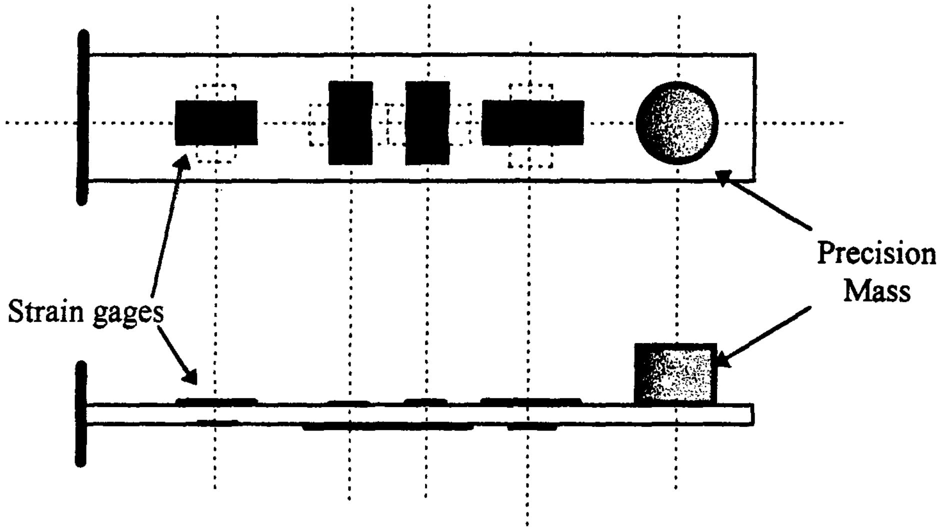


FIGURE 1. Apparatus Arrangement for Stress Analysis and Computer Comparison

- For a more detailed drawing of gage locations and other specifics, see Figure 2.

III. Procedure

The experiment was carried out by following the procedure listed below:

1. Obtain the Ambient (room) Temperature Measurement
2. Trim a 3/16 x 1 x 2 - 1 / 2 inch strip of aluminum and file rough edges
3. Prepare the beam for attaching a strain gage
4. Burnish marks along and perpendicular to the centerline of the beam. Gages must be placed in approximately even increments along the beam alternating axially and laterally as shown in Figure 1.
6. Select and install the gage according to instructions presented in the Student Manual for Strain Gage Technology (Reference 1)
7. Clamp the beam into the fixture
8. Connect the two gage lead wires to the strain indicator system in a half-bridge configuration (see the instruction manuals for the SB 10 Switch and Balance unit and the P 3500 Strain Indicator unit (References 2 and 3)

9. Also use a temperature compensation gage (provided in lab) and attach it into the bridge circuit in the proper fashion.

10. Create a known and (nearly) uniform bending stress field by loading the free end of the cantilever beam with precision masses in the amount of 400 grams (see Wolf, Reference 4 for a discussion of stresses in cantilever beams with rectangular sections)

11. Record the strains at each of the eight (8) gage locations as shown on the strain indicator, and the corresponding mass making up the bending moment strain.

12. Repeat the procedure with the same load of 400 grams until five (5) data points are obtained for each gage location.

13. Reduce data to obtain a stress profile

14. Have a Finite Element Analysis of the beam run for comparison.

IV. Experimental Observations

The mass value for this laboratory project is four hundred (400) grams from the precision masses, and strain, ε, values ranged from:

axial positions: 128 to 44 $\mu\varepsilon$
lateral positions: 41 to 13 $\mu\varepsilon$

The values for the calculated value of Axial Stress developed at points:

A: 1270.42 psi
B: 852.23 psi
C: 697.68 psi
D: 449.40 psi

During the data taking, the following observations were made:

1. The amount of strain, ε, indicated decreased as the amount of distance along the beam from the flexure frame increased.
2. Care was taken to insure that the cantilever beam apparatus was not bumped or disturbed so as not to affect strain gage results obtained.
3. Because the P 3500 strain indicator is digital, a ½ digit truncation occurs in the strain, ε, data obtained.
4. After each data point was collected the apparatus was allowed to zero in order to confirm that there was no drift in the readings obtained to provide a bias error.

V. Calculations

Calculated values are for position A on Table 1. and statistical information from the attached spreadsheet titled Table 2.

- For the calculation of the value load, P, in pounds:

$$\mathbf{P_{(lbs)} = P_{(grams)} * (2.20461164185 \times 10^{-3}\ lb\ /\ 1\ gram)}$$

$$\mathbf{P_{(lbs)} = 400\ grams * (2.20461164185 \times 10^{-3} / 1\ gram) = .882\ lbs}$$

- For the calculation of the corrected value of longitudinal strain, ε_x:

$$\varepsilon_x = ((1 - \nu_0 * K_t)/(1 - K_t^2))/(\varepsilon_{x1} + K_t * \varepsilon_{y1})$$

$$\varepsilon_x = ((1 - .285 * .010)/(1 - .010^2))/(127.8 + .010 * 40.8)$$

$$\varepsilon_x = 127.0\ \mu\varepsilon$$

Where, ε_x is the *corrected* longitudinal strain, ν_0 is the constant .285, K_t is the transverse sensitivity for the strain gage (from strain gage data sheet), ε_{x1} & ε_{y1} are two observed but *uncorrected* orthogonal strains.

- For the calculation of the value for normal stress, σ, at the strain gage:

$$\mathbf{E = \sigma / \varepsilon \qquad \sigma = E\varepsilon \qquad \sigma = 10 \times 10^6 * 127.0\ \mu\varepsilon}$$

$$\mathbf{\sigma = 1270.42\ psi}$$

- For the calculation of percent error of the Calculated Axial Stress vs. Computer Generated Axial Stress:

% Error = [| Measured Value - Actual Value | / Actual Value] * 100

$$\mathbf{\%\ Error = [\ |\ 1270.42\ \mu\varepsilon - 1261.22\ \mu\varepsilon\ |\ / 1261.22\ \mu\varepsilon\ ]*100}$$

% Error = 0.73 %

- For the value of the slope of the regression line of the plot for *Actual Pounds vs. Indicated Pounds* data:

intercept = a = (Σ yi Σ xi2 - Σ xi Σ xi yi) / (n Σ xi2 - (Σ xi)2
from the excel worksheet intercept, a = .2058

slope = b = $(\, \mathbf{n} \sum x_i y_i - \sum x_i \sum y_i) / (\, \mathbf{n} \sum x_i^2 - (\sum x_i)^2$
from the excel worksheet slope, b = .965

- To determine the regression line formula:

$$\mathbf{y = ax + b \qquad y = .935\,x + 33.31}$$

The formula for the regression line is: y = .935 x + 33.31

- The correlation coefficient squared or the r^2 value is determined for this equation from the equation:

$$\mathbf{r^2 = [\, \sum (y (x_i) - y_m)^2 \,] / [\, S^2 + \sum (y (x_i) - y_m)^2]}$$
From the Excel Worksheet the r^2 value is .96478

- The value of the percentage of scatter for the data about the regression line is calculated from the equation:

% scatter = ($\sqrt{}$ 1 - r^2) * 100% The value for this number is 18.77%

VI. Error Analysis

The statistics for the data obtained for the stress profile in the aluminum beam were completed and the results as follows. From Table 3., a student - T test was completed for the readings taken from each of the strain gage locations. The error band was found to the 95th percentile. The statistics for the regression analysis for *Calculated Axial Stress vs. FEA Generated Axial Stress* for the aluminum cantilever beam confirms that the value of the regression line accurately represents the values of the *Calculated Axial Stress vs. FEA Generated Axial Stress* to the 81.33 % level. The correlation coefficient (r) value is equal to .98223 for the experiment data fit, and the correlation coefficient squared (r^2) value is equal to .96478. No outliers were present in the data obtained.

VII. Results, Conclusions, and Recommendations

The experimental data obtained through this exercise were obtained during several sessions and is presented and reduced on the spreadsheets labeled Table 1 and Table2. The primary results and conclusions are as follows:

1. The comparison between the calculated values for the axial stress at the gage locations was generally comparable to the Algor Finite Element Analysis results.

2. The percentage of error between the calculated and computer generated data was reasonable at values of:

Point A:	0.73 %
Point B:	12.52 %
Point C:	0.79 %
Point D:	7.84 %

3. The regression line representing the reduced value of the curve for *Calculated Axial Stress vs. FEA Generated Axial Stress* was calculated to be **y = .935 x + 33.31** where x is equal FEA Results and y is the calculated axial stress values present for our experiment.

4. This regression calculation for the graph of *Calculated Axial Stress vs. FEA Generated Axial Stress* was calculated to be 81.33 % representative of the data collected with 18.77 % of the data being represented by scatter of the data obtained. Although this is not an ideal linear relationship it is still relatively acceptable.

5. The data collected was consistent: There were no apparent outliers in the data sample.

As a recommendation for this lab exercise I would recommend finding a better method by which to secure the wires and gages to the aluminum bar. Many gages were lost or damaged because wires were pulled loose or completely off.

VIII. References

1. Student Manual for Strain Gage Technology, Bulletin 309 D
2. SB 10 Switch and Balance Unit Manual
3. P 3500 Strain Indicator Manual.
4. Statics and Strengths of Materials. Mech 240 textbook.
5. Mechanical Measurements. Mech 221 textbook

Table 1. Stress Profile in an Aluminum Cantilever Beam

Stress Profile in Aluminum Cantilever Beam

			Indicated Strain		Corrected Strain	Modulus of	Axial Stress	Axial Stress	%
Position	Load	Load	ε_x	ε_y	ε_x	Elasticity, E	Developed	From FEA	Error
No.	(grams)	(lbs)	ε μstrain	ε μstrain	ε μstrain	psi	psi	psi	
A	400	0.882	127.8	40.8	127.0	10E+06	**1270.42**	**1261.22**	**0.73%**
B	400	0.882	85.8	34.2	85.2	10E+06	**852.23**	**974.16**	**12.52%**
C	400	0.882	70.2	24.0	69.8	10E+06	**697.68**	**703.23**	**0.79%**
D	400	0.882	45.2	13.6	44.9	10E+06	**449.40**	**416.73**	**7.84%**

Table 2. Regression Data for *Calculated Axial Stress vs. FEA Generated Axial Stress*

Axial Stress Developed psi	Axial Stress From FEA psi
1270.42	**1261.22**
852.23	**974.16**
697.68	**703.23**
449.40	**416.73**

Slope = 0.935
Intercept = 33.31117
Correlation= 0.982234
Correl^2= 0.964784
18.77%

Table 3. T-test data for the values of the calculated axial stresses.

Readings for Trials	Gage Position and Direction							
	A_a	A_l	B_a	B_l	C_a	C_l	D_a	D_l
1	127	40	86	35	70	24	44	13
2	128	41	87	34	71	24	45	13
3	128	41	85	34	70	24	45	14
4	128	41	85	34	70	24	46	14
5	128	41	86	34	70	24	46	14

A_a
Statistics

x-bar	127.8	
Sx	0.447	
n	5	
t .025	2.776	
95%	0.555	
n-1	4	
95% x-range	127.2	128.4
3*Sx	1.342	

Outliers outside of the values:

minimum	126.5
maximum	129.1

A_l
Statistics

x-bar	40.8	
Sx	0.447	
n	5	
t .025	2.776	
95%	0.555	
n-1	4	
95% x-range	40.2	41.4
3*Sx	1.342	

Outliers outside of the values:

minimum	39.5
maximum	42.1

B_a
Statistics

x-bar	85.8	
Sx	0.837	
n	5	
t .025	2.776	
95%	1.039	
n-1	4	
95% x-range	84.8	86.8
3*Sx	2.510	

Outliers outside of the values:

minimum	83.3
maximum	88.3

B_l
Statistics

x-bar	34.2	
Sx	0.447	
n	5	
t .025	2.776	
95%	0.555	
n-1	4	
95% x-range	33.6	34.8
3*Sx	1.342	

Outliers outside of the values:

minimum	32.9
maximum	35.5

C_a
Statistics

x-bar	70.2	
Sx	0.447	
n	5	
t .025	2.776	
95%	0.555	
n-1	4	
95% x-range	69.6	70.8
3*Sx	1.342	

Outliers outside of the values:

minimum	68.9
maximum	71.5

C_l
Statistics

x-bar	24.0	
Sx	0	
n	5	
t .025	2.776	
95%	0.000	
n-1	4	
95% x-range	24.0	24.0
3*Sx	0.000	

Outliers outside of the values:

minimum	24.0
maximum	24.0

D_a
Statistics

x-bar	45.2	
Sx	0.837	
n	5	
t .025	2.776	
95%	1.039	
n-1	4	
95% x-range	44.2	46.2
3*Sx	2.510	

Outliers outside of the values:

minimum	42.7
maximum	47.7

D_l
Statistics

x-bar	13.6	
Sx	0.548	
n	5	
t .025	2.776	
95%	0.680	
n-1	4	
95% x-range	12.9	14.3
3*Sx	1.643	

Outliers outside of the values:

minimum	12.0
maximum	15.2

Ferris State University

MEMORANDUM

DATE: April 23, 1997

TO: Mr. Jeff Kaiser
Mr. Jeff O'Neill

CC: Dr. George Olsson

FROM: Chuck Drake
Mechanical Engineering Technology
Swan 109
x2788

RE: Finite Element Model of Aluminum Bar

As requested, I have made a finite element model of the aluminum bar subjected to a bending load according to your drawing (copy attached). Results appear below.

The model was created with 2-dimensional plane stress elements using Algor (TM) software. 560 elements were used in the model. The nodes at the top and bottom of the left end of the bar were fixed; the load was applied as a uniform pressure over 1 inch of the model. Although these latter simplifications may be somewhat unrealistic, the strain gage locations should be sufficiently distant from the boundary conditions and loads that any effect is minimal. Since a sampling of the results agreed very closely with hand calculations, no mesh refinement study was done.

Attached please find two plots showing color-dithered stresses.

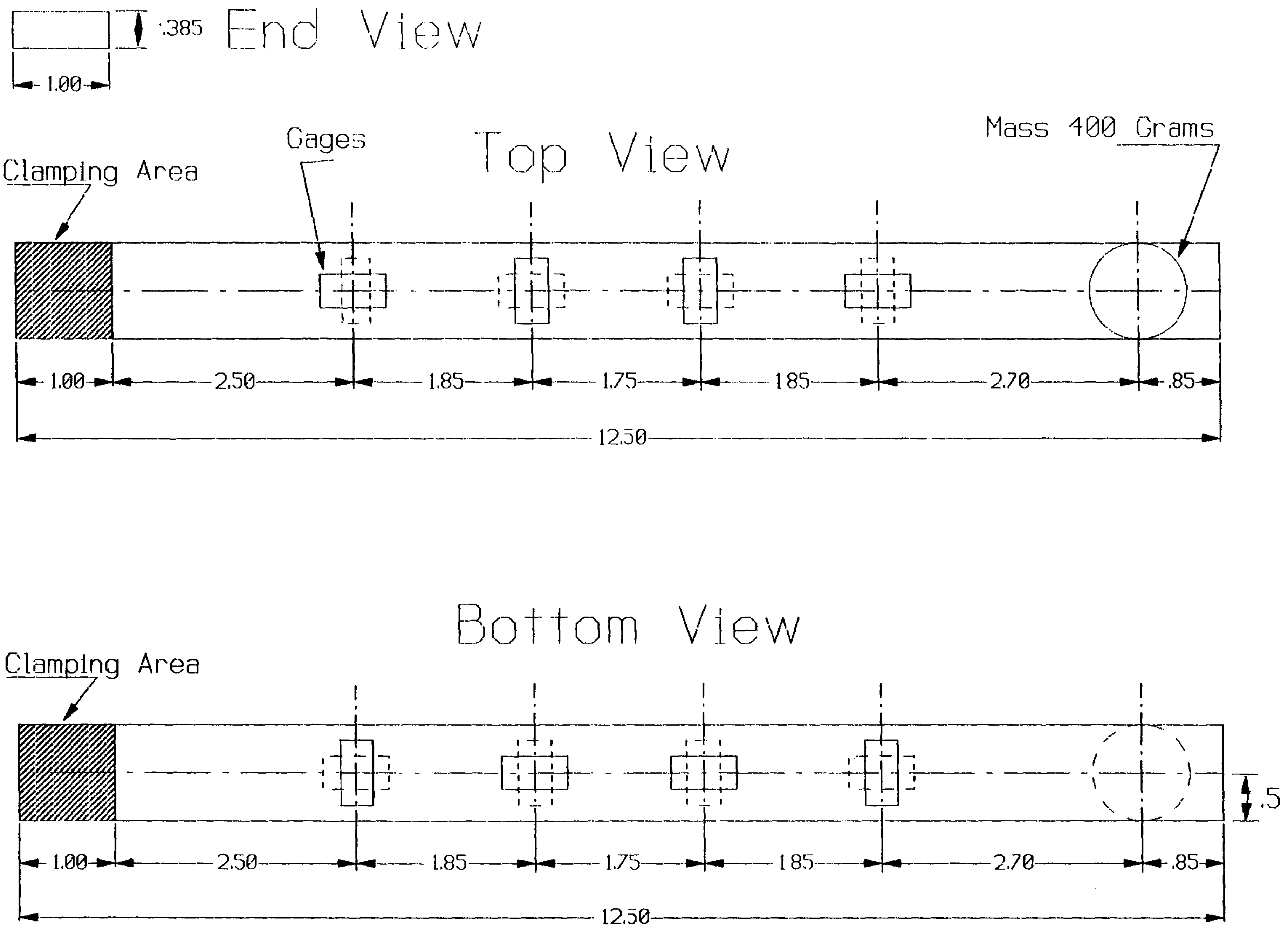
RESULTS:

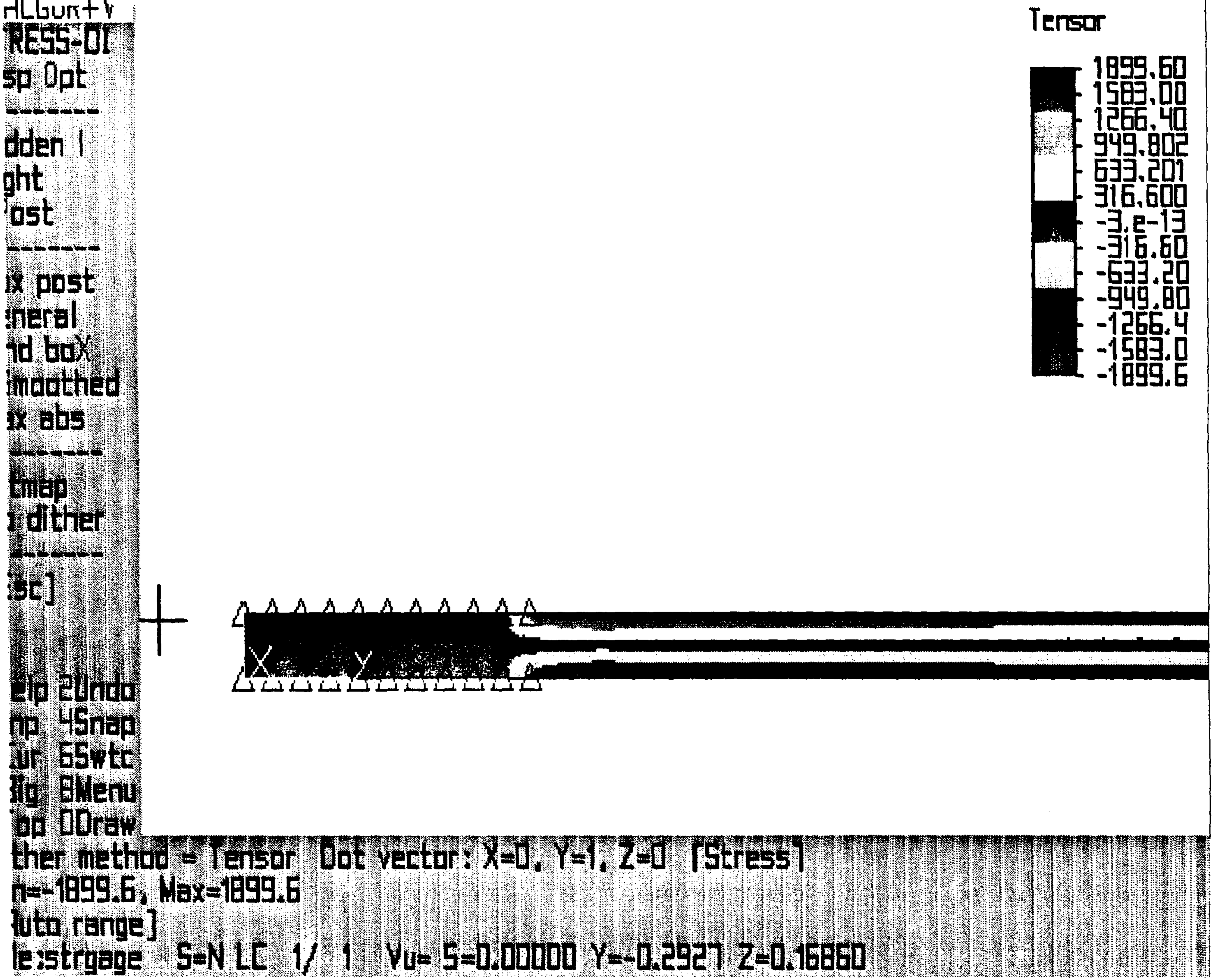
POINT	X (inches from support)	normal stress on top (psi)	normal stress on bottom (psi)
A	3.50	1261.22	-1261.22
B	5.35	974.157	-974.157
C	7.10	703.226	-703.226
D	8.95	416.739	-416.739

+ tension - compression

Attachments

Figure 2. Cantilever Beam Strain Gage Placements and Required Dimensions





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ther method = Tensor  Dot vector: X=0, Y=1, Z=0  [Stress]
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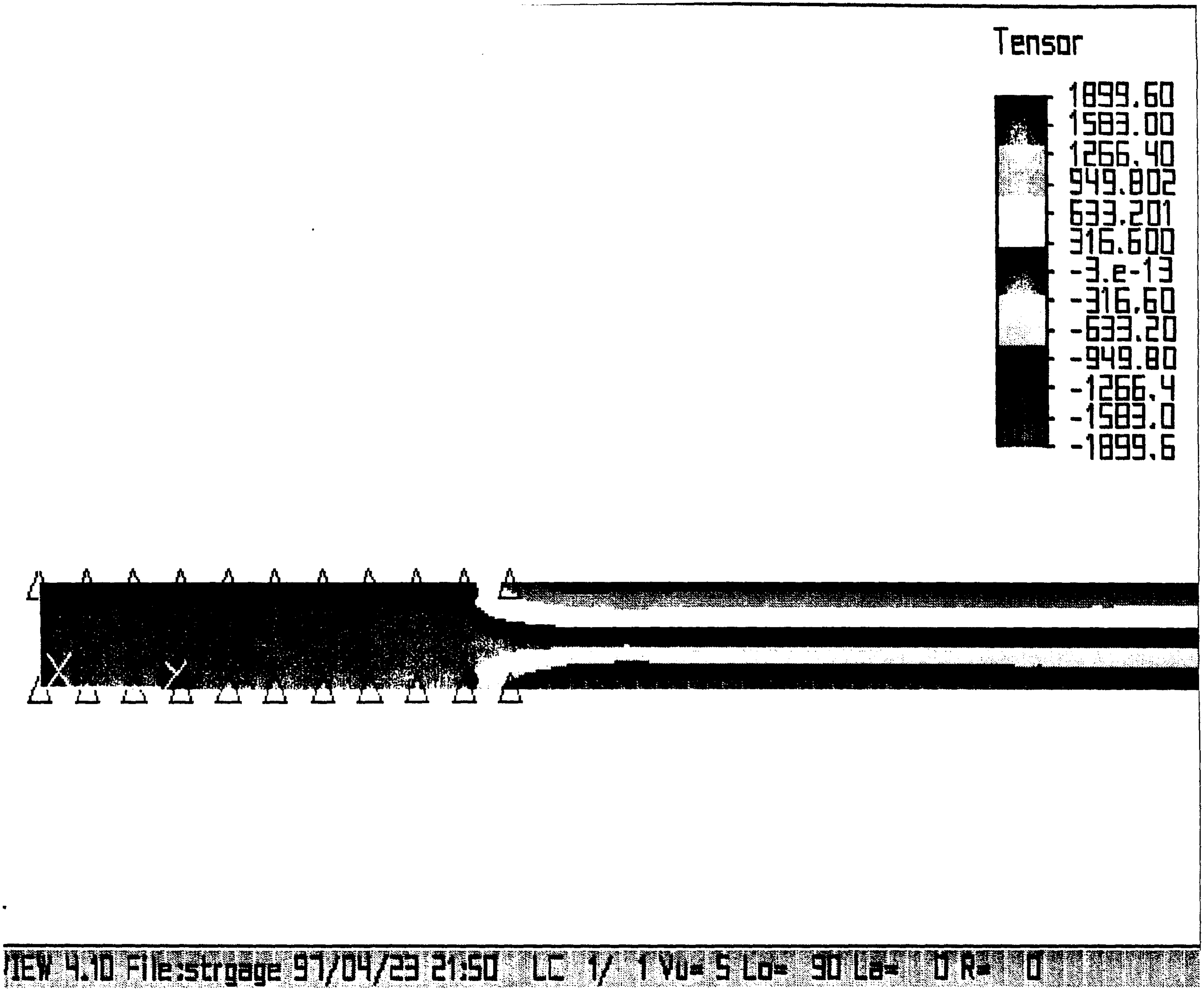

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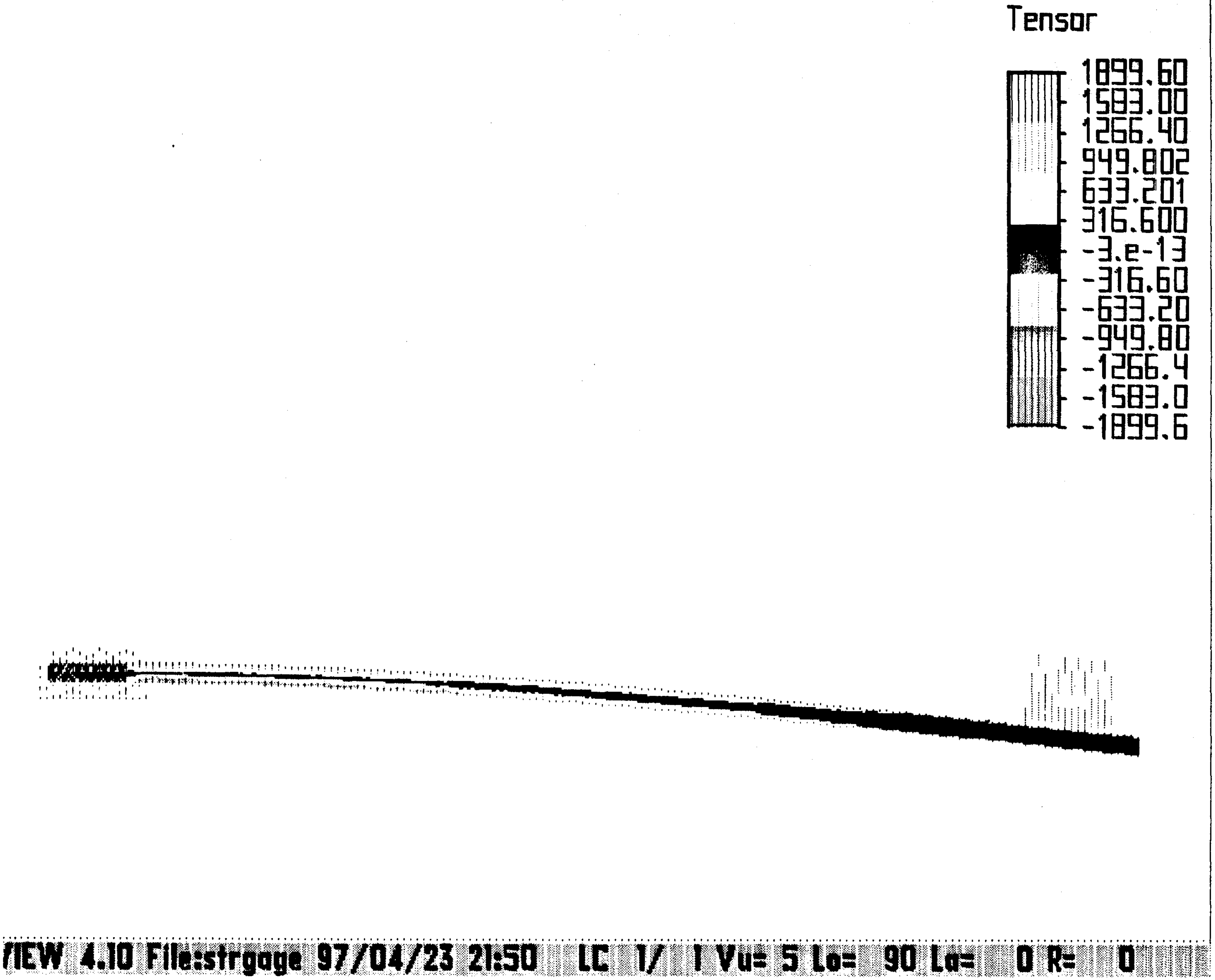


VIEW 4.10 File:strgage 97/04/23 21:50 LC 1/ 1 Vu= 5 Lo= 90 La= 0 R= 0

Hand Strength Comparitor

using a full-bridge strain gage circuit

Mech 221
Section 212
Mechanical Measurements with Computer Applications

Mechanical Engineering Technology Program
Ferris State University

April 30, 1997

by
J. M. O'Neill
Jeff Kaiser
Lab Group #5

Summary

The objective of this laboratory project was to develop an apparatus which was capable of comparing the strength of a persons hand strength or grip. This is to be done by developing strain in two fixed cantilever beams of steel pipe. The deflection of the two beams will be measured by four strain gages mounted on the top and bottom of the bending members. These gages will be arranged on the strain indicator in a full bridge circuit to obtain a strain value magnification of 4 times. The comparitor apparatus was calibrated and a gage factor of 1.826 was required to obtain a relationship of strain to pounds applied. The readings were obtained from the testing apparatus using fish scale that were also calibrated. Readings were obtained from the fish scale at values from 2 to 10 kilograms in 2 kilogram increments for calibration. This will be completed to obtain a value of 10.6 lbs on the scale for 10 lbs and 20.9 lbs on the scale as the equivalent for 20 lbs. This was found by the formula:

$$\textit{Actual Pounds} = .965 * .2058 * \textit{Indicated Pounds}$$

This equation is representative of 95.79 % of the data obtained and only 4.21 % is represented by scatter about the regression line. Thus, our apparatus is capable of comparing the hand strength applied to the apparatus.

Contents

I. Objective

The purpose of this laboratory project was to develop an apparatus which was capable of comparing the strength of a person's hand strength. This is to be done by developing strain in two fixed cantilever beams of steel pipe. The deflection of the two beams will be measured by four strain gages mounted on the top and bottom of the bending members. These gages will be arranged on the strain indicator in a full bridge circuit to obtain a strain value magnification of 4 times and calibrated to output in pounds applied.

II. Apparatus

The apparatus for this experimental exercise is diagrammed in Figure 1, (below) and consists of the following component parts and materials.

	Count	Device
1.	1	Frame fixture for mounting of the two pipes
2.	2	Standard ½ inch steel pipe in 8" lengths
3.	2	Flange brackets for mounting pipes
4.	8	¼ inch bolts, nuts and washers 1" long
5.	4	Strain gage suitable for steel (Micro-Measurements EA-06-060LZ-120)
6.	1	Strain gage application kit and supplies
7.	1	Temperature controlled soldering iron and soldering supplies
8.	1	Engineering scale
9.	1	Set of precision gram masses
10.	1	Wheatstone bride completion circuit (SB 10)
11.	1	Strain Indicator (P 3500)

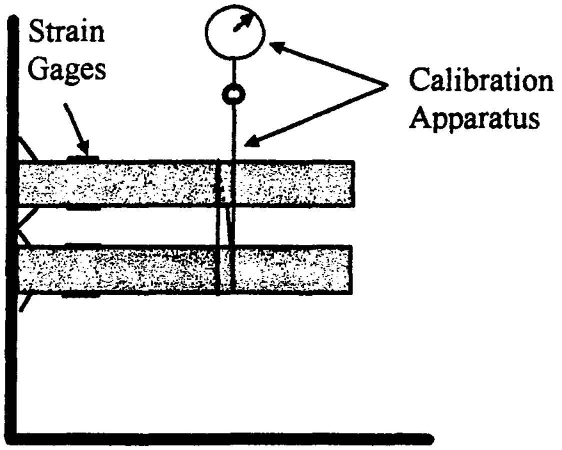


FIGURE 1. Apparatus Arrangement for Hand Strength Comparison

- For a more detailed design of the apparatus see Figure 2.

III. Procedure

The experiment was carried out by following the procedure listed below:

1. Construct base following plans in Figure 2.
2. Trim pipes to appropriate lengths and attach to base with flanges
3. Prepare the pipes for attaching of strain gages
4. Burnish marks along and perpendicular to the centerline of the beam at the appropriate location.
5. Select and install the gage according to instructions presented in the Student Manual for Strain Gage Technology (Reference 1)
6. Clamp the beam into the fixture
7. Connect the two gage lead wires from each of the four (4) gages to the strain indicator system in a full-bridge configuration (see the instruction manuals for the SB 10 Switch and Balance unit and the P 3500 Strain Indicator unit (References 2 and 3)
8. Create a known and (nearly) uniform bending stress field by loading the free end of the cantilever beams by squeezing together the two beams with your hand (see Wolf, Reference 4 for a discussion of stresses in cantilever beams with rectangular sections)
9. Calibrate the apparatus using the rope and fish-scale system shown in Figure 1.
10. Obtain strength reading in pounds for hand strength from properly calibrated device.
11. Repeat the procedure

IV. Experimental Observations

Mass values for this experiment ranged from 2000 to 10000 grams on the precision masses used and the fish-scales used indicated in the range from 0 to 24 pounds. The values calculated for the calibration of the fish scale used were a slope of .965 and an intercept of .2058:

1. The amount of weight indicated increased as the amount of mass that was placed at the loading point of the scale.
2. Care was taken to insure that the apparatus was not bumped or disturbed so as not to affect results obtained.
3. Because the fish-scale indicator only has divisions in 1/4 of a pound increments truncation occurs in the weight in pounds data obtained.
4. After each data point was collected the apparatus was allowed to zero in order to confirm that there was no drift in the readings obtained to provide a bias error.

V. Calculations

The *Actual Pounds vs. Indicated Pounds* data was reduced through the use of an Excel Spreadsheet.

Calculated values are for trials on Table 2. and statistical information from the attached spreadsheet titled Table 2..

- For the calculation of the value load, P, in pounds:

$$\mathbf{P_{(lbs)} = P_{(grams)} * (2.20461164185 \times 10^{-3}\ lb / 1\ gram)}$$

$$\mathbf{P_{(lbs)} = 2000\ grams * (2.20461164185 \times 10^{-3} / 1\ gram) = 4.409\ lbs}$$

- For the value of the slope of the regression line of the plot for *Actual Pounds vs. Indicated Pounds* data:

intercept = a = (Σ yi Σ xi2 - Σ xi Σ xi yi) / (n Σ xi2 - (Σ xi)2
from the excel worksheet intercept, a = .2058

slope = b = $\mathbf{(n \sum x_i y_i - \sum x_i \sum y_i) / (n \sum x_i^2 - (\sum x_i)^2}$
from the excel worksheet slope, b = .965

◆ To determine the regression line formula:

$y = ax + b$ $\quad$ $y = .965\,x + .2058$ $\quad$ $\underline{4.46 \text{ lbs}} = .965 * \underline{4.00 \text{ lbs}} + .2058$

The formula for the regression line is: $y = .965\,x + .2058$

◆ The correlation coefficient squared or the r^2 value is determined for this equation from the equation:

$$r^2 = [\,\Sigma\,(\,y\,(\,x_i\,) - y_m\,)^2\,]\,/\,[\,S^2 + \Sigma\,(\,y\,(\,x_i\,) - y_m\,)^2]$$

From the Excel Worksheet the r^2 value is .9991

◆ The value of the percentage of scatter for the data about the regression line is calculated from the equation:

% scatter = $(\sqrt{1 - r^2}) * 100\%$ The value for this number is 4.21%

VI. Error Analysis

The statistics for the regression analysis for *Actual Pounds vs. Indicated Pounds* for calibration of the Hand Strength Comparitor confirms that the value of the regression line accurately represents the values of the *Actual Pounds vs. Indicated Pounds* graph at a 95.79 % level. The correlation coefficient (r) value is equal to -.9991 for the experiment data fit, and the correlation coefficient squared (r^2) value is equal to -.9982. This data provides an accurate calibration curve for the data of indicated and actual weight.

VII. Results, Conclusions, and Recommendations

The experimental data obtained through this exercise were obtained during several sessions and is presented and reduced on the spreadsheet labeled Table 2 and the regression line and data are plotted on the attached graph titled *Actual Pounds vs. Indicated Pounds*. The primary results and conclusions are as follows:

1. The gage factor for the apparatus that provides us with a relationship between pounds applied and pounds indicated is 1.826 for the full bridge circuit.
2. The regression line representing the reduced value of the curve for *Actual Pounds vs. Indicated Pounds* was calculated to be **$y = .965x + .2058$** where x is equal to pounds indicated on the fish-scale and y is the actual pounds present for our experiment.
3. This regression calculation for the graph of *Actual Pounds vs. Indicated Pounds* was calculated to be 95.79 % representative of the data collected with only 4.21% of the data being represented by scatter of the data obtained.
4. The data collected was consistent: There were no apparent outliers in the data sample.

VIII. References

1. Student Manual for Strain Gage Technology, Bulletin 309 D
2. SB 10 Switch and Balance Unit Manual
3. P 3500 Strain Indicator Manual.
4. Statics and Strengths of Materials. Mech 240 textbook.
5. Mechanical Measurements. Mech 221 textbook

Table 1. Calculations for Fish-Scale Calibration

Calculations for Calibration of Fish Scales for Apparatus Calibration

Scale A Kilograms	Weight Pounds	Indicated Pounds	Actual Pounds
0	0.00	0.00	0.21
2	4.41	4.00	4.46
4	8.82	8.50	8.71
6	13.23	13.00	12.97
8	17.64	18.25	17.22
10	22.05	22.25	21.48
8	17.64	18.25	17.22
6	13.23	14.25	12.97
4	8.82	8.75	8.71
2	4.41	4.25	4.46
0	0.00	0.00	0.21
2	4.41	4.00	4.46
4	8.82	9.00	8.71
6	13.23	13.50	12.97
8	17.64	18.00	17.22
10	22.05	22.50	21.48
8	17.64	18.25	17.22
6	13.23	13.75	12.97
4	8.82	9.25	8.71
2	4.41	4.25	4.46
0	0.00	0.00	0.21

Scale A

Slope = 0.965 10 lbs = 10.6
Intercept = 0.20575 20 lbs = 20.9
Correlation= 0.99911
Correl^2= 0.99823
4.21%

Table 2. Material Calculations for the Hand Strength Comparitor

Material Calculations for the Hand Strength Comparitor

Material used: 6" moment arm of half inch schedule 40 steel pipe

Strain Reading for 20 and 100 lbs of force

Length of arms, L = 6 in.
Force Applied, P1 = 20 lbf
Force Applied, P2 = 100 lbf
Outside Diameter, D = 0.840 in. (St.Stren.)
Moment of Inertia I = 0.017 in.^{4} (St.Stren.)
Modulus of Elasticity E = 30E+06 psi (St.Stren.)

ε for P1 99 $\mu\varepsilon$
ε for P2 494 $\mu\varepsilon$

Actual reading on meter:
for P1= 395 $\mu\varepsilon$
for P2= 1976 $\mu\varepsilon$

The reading for 20 lbf applied will be 395 microstrain and the reading at 100 lbf will be 1976 microstrain.

Material used: 8" moment arm of 3 / 4 inch schedule 40 steel pipe

Strain Reading for 20 and 100 lbs of force

Length of arms, L = 8 in.
Force Applied, P1 = 20 lbf
Force Applied, P2 = 100 lbf
Outside Diameter, D = 1.050 in. (St.Stren.)
Moment of Inertia I = 0.037 in.^{4} (St.Stren.)
Modulus of Elasticity E = 30E+06 psi (St.Stren.)

ε for P1 76 $\mu\varepsilon$
ε for P2 378 $\mu\varepsilon$

Actual reading on meter:
for P1= 303 $\mu\varepsilon$
for P2= 1514 $\mu\varepsilon$

The reading for 20 lbf applied will be 395 microstrain and the reading at 100 lbf will be 1976 microstrain.

Figure 2. Drawing of Hand Strength Comparitor Apparatus

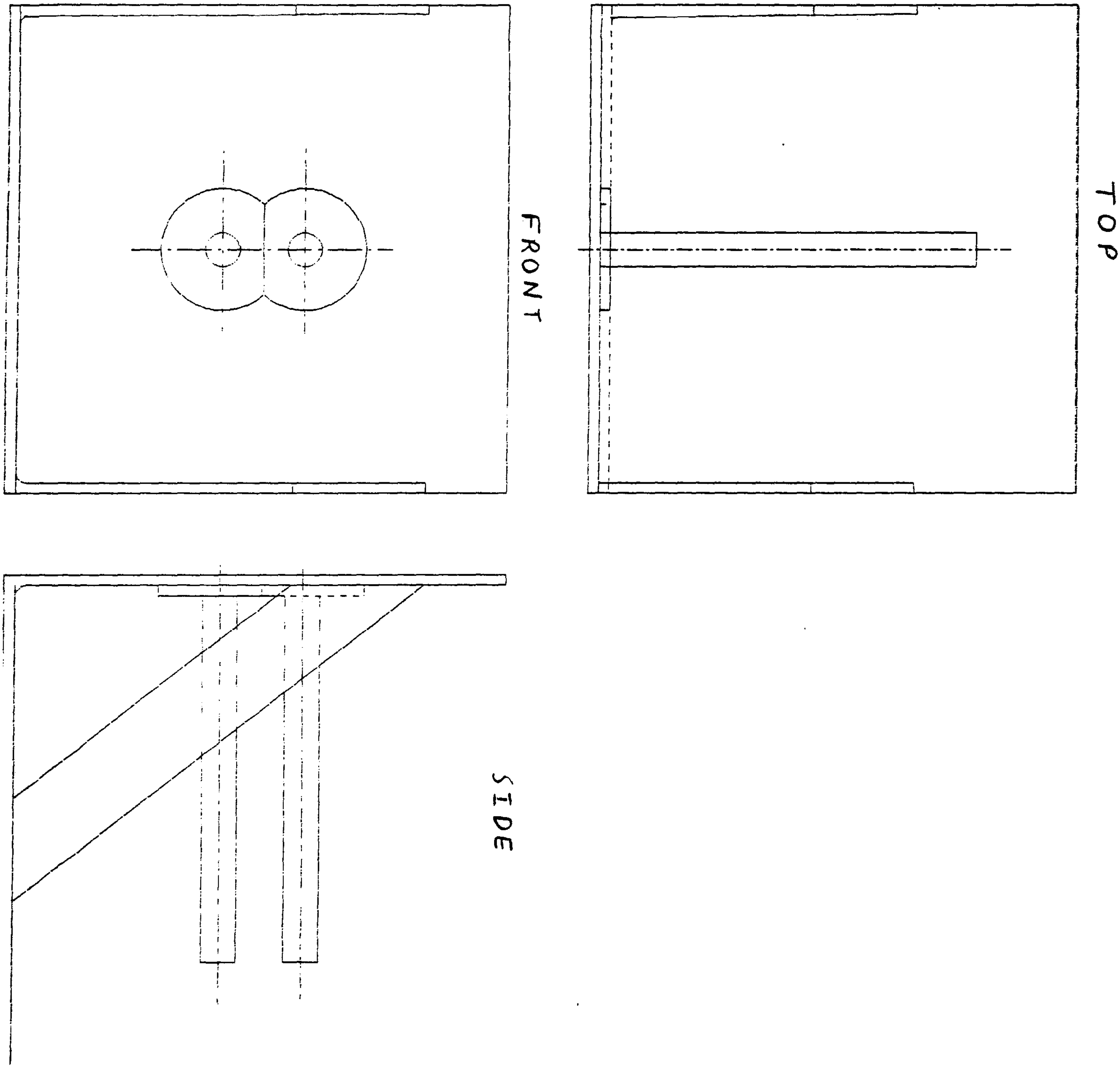
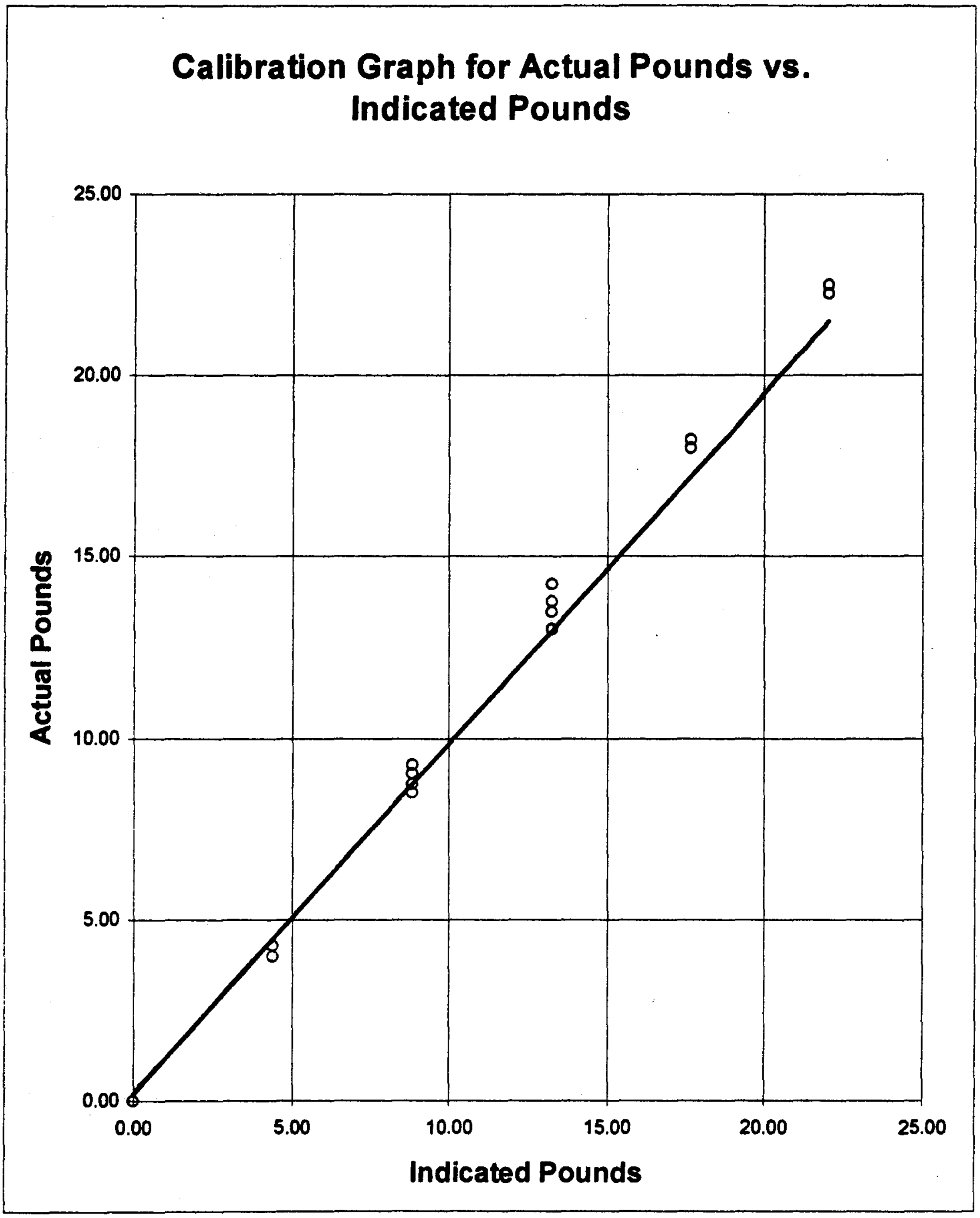


Figure 3. Graph *Actual Pounds vs. Indicated Pounds*



COCA COLA POP CAN
PRESSURE MEASUREMENT

by

Group #1
Ryan W. Livingston and Janet Tichelaar

Ferris State University

MECH 221
Mechanical Measurements with Computer Applications

April 29, 1997

MECH 221 COCA COLA POP CAN PRESSURE MEASUREMENT

SUMMARY

The purpose of this experiment is to determine the internal pressure of a randomly selected set of Coca Cola pop cans. To accomplish this, rosette-style strain gauges will be used in order to determine the stresses on the cans. This information, along with the material's modulus of elasticity (determined in the second section of this group project), is used to find the pressure inside the can.

The internal pressure will ultimately be determined using a formula for cylindrical pressure vessels:

$$\sigma_{hoop} = \frac{r * p}{t}$$

Where: **σ** is the stress on the can in the "hoop" or circumfrencial orientation.
t is thickness of the can's material.
r is the radius of the can.
p is the internal pressure of the can.

The main subject of this project is to find the pressure in a can that has been left at rest. We will, however, also analyze the pressures inside of cans that have been shaken and heated.

MECH 221 COCA COLA POP CAN PRESSURE MEASUREMENT

CONTENTS

MECH 221 COCA COLA POP CAN PRESSURE MEASUREMENT

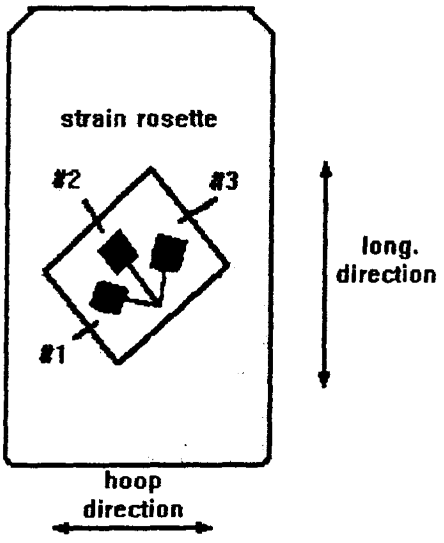
I. OBJECTIVE

The main objective of this experiment is to determine the pressure inside of a randomly selected set of Coca Cola pop cans, with the use of strain gauges and information regarding the material's properties.

II. APPARATUS

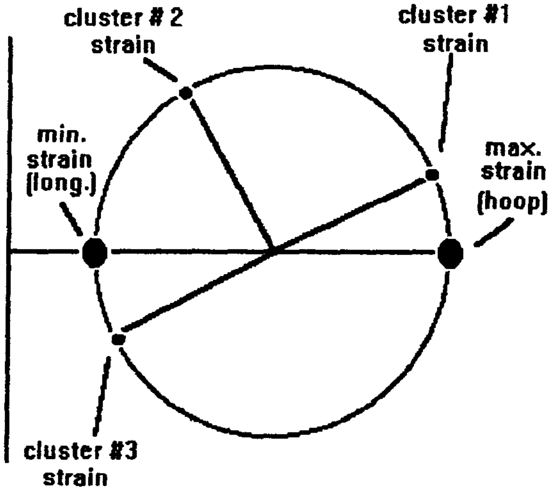
1. 3-cluster rosette style strain gauges suitable for aluminum (EA-13-060RZ-120)
2. Strain gauge application kit and supplies
3. Temperature-controlled soldering iron and soldering supplies
4. Heating plate and large water-filled container
5. Thermometer
6. Micrometer with venier scale
7. Engineering scale
8. 4 cans of Coca Cola (w/caffeine, original formula, regular)
9. Wheatstone bridge completion circuit and strain indicator (SB-10 Micro-Measurement Box)
10. Strain indicator (Micro-Measurements P3500)

COKE CAN
(side view)



(strain around the circumfrence)

MOHR'S CIRCLE



III. PROCEDURE

1. Measure and record the dimensions of the Coca Cola cans.

2. Prepare the cans for attaching a strain gauge.

3. Burnish marks at the pre-determined locations for purposes of installing the strain gauge.

4. Install the gauge according to the instructions provided in the Student Manual for Strain Gauge Technology.

5. Connect the six gauge lead wires to the strain indicator system in a half bridge configuration in order to allow for parallel-connected temperature compensating rosette.

6. After zeroing the strain readings, open the can to induce a strain that is equal to the difference between its pressurized state under atmospheric pressure and its unpressurized state.

7. Record the strain of the three clusters on the rosette.

8. Repeat the procedure with the can to be shaken, recording the measurements after it has been shaken but not opened. The resulting pressure, determined later, can simply be added to that of the can opened at rest.

9. On the can to be heated, zero the gauge and bring it up to a relatively hot temperature which is measured and recorded for reference with a thermometer. **Do not exceed 70 degrees Celsius! At temperatures close to, or exceeding this value, THE CAN WILL RUPTURE!** Heating is accomplished with the use of a heating plate and a bath of water. Simply immerse the can in the water and allow it time (approx. 30 min.) to reach the temperature of the bath.

10. Record the strain which will, again, be used to derive a pressure that will simply be added to that of the can opened at rest.

11. Use Mohr's Circle of strain to determine the minimum and maximum strains which will represent the strains in the longitudinal and circumfrencial directions, respectively.

12. Determine the internal pressure using the formula for cylindrical internal pressure vessels.

IV. DATA REDUCTION, SAMPLE CALCULATIONS, AND STATISTICS

All recorded data and derived statistics are given on the attached spreadsheet, entitled "POP CAN PRESSURES".

To find the Radius of Mohr's Circle, the following formula is used.

$$\frac{1}{2}\sqrt{2(\varepsilon_1-\varepsilon_2)^2+(\varepsilon_2-\varepsilon_3)^2}$$

Where $\varepsilon_1, \varepsilon_2, \varepsilon_3$ are the values on the corresponding picture labeled "COKE CAN" under the section "Apparatus" in this lab report.

For example:

$$\frac{1}{2}\sqrt{2(1573-658)^2+(658-261)^2} = 705\mu\varepsilon$$

The value of the principal normal stresses (maximum and minimum) can be found using the equations:

$$\max = \frac{1}{2}(\varepsilon_1+\varepsilon_3)+radius$$

$$\min = \frac{1}{2}(\varepsilon_1+\varepsilon_3)-radius$$

For example:

$$1622\mu\varepsilon = \frac{1}{2}(1573+261)+705$$

The Hoop Stress is found with this formula:

$$\sigma_{hoop} = \frac{E\left(\varepsilon_{hoop}+\varepsilon_{long.}\nu\right)}{1-\nu^2}$$

For example:

$$\sigma_{hoop} = \frac{68{,}008\,MPa(1622\mu\varepsilon + 212\mu\varepsilon(.3))}{1-.3^2}$$

$$\boldsymbol{\sigma_{hoop} = 125.986\ \mathrm{MPa}}$$

Finally, pressure is found by the formula for cylindrical pressure vessels.

$$\sigma_{hoop} = \frac{t * p}{r}$$

For example:

$$125.986\,MPa = \frac{33.058_{mm} * p}{.114_{mm}}$$

$$\boldsymbol{p = 367{,}767\ \mathrm{Pa} = 53.34\ \mathrm{psi}}$$

V. RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

All of the resulting pressures are given on the attached spreadsheet, entitled "POP CAN PRESSURES". Note that the final "shaken and opened" pressure are not considered valid. This is most likely due to the abrupt and inaccurate nature of collecting these particular readings. However, the main objective of the project, to find a pressure inside of a "left alone" can, was found along with the heated and shaken cans which provided seemingly appropriate results.

The conclusions of our experiment were quite satisfactory, although we did originally questioned the validity of our strain readings. As mentioned in the "template" lab performed by MGI (Measurements Group, Inc.), our strains would not be the ideal 2:1 ratio of hoop to longitudinal strain. In an infinitely long and consistent cylinder, the measured strains would approach this relation. In our case that ratio was **6.4:1**, which caused us to believe that the experiment was completely invalid. However, if the "fine print" is read in the lab, as performed by MGI, one notes that they also experienced a similar result and obtained a ratio of approximately **5:1** of hoop to longitudinal stress. According to MGI, this ratio is a result of the "material properties of the cylinder".

The formula used for calculating the stresses in the cylinder, from the strain data, did produce ratios of hoop to longitudinal stress that were relatively close to 2:1, which compensated for the seemingly ill-related strains.

Of course, the Coca Cola cans are not perfect cylinders. When the pressure at which the cans are expected to rupture is determined, is must be understood that we are disregarding the "break open" top of the can and impact/pressure relief features which make up the concave section on the can's bottom. The derived pressure at which the pop can will rupture is therefore a maximum value which will probably not be reached. More specifically, the can will most likely not rupture in a direction down the side of the can, parallel to its longitudinal axis, before something else relieves the internal pressure.

As for recommendations, make sure that no one in the future is allowed to heat the pressurized cans over 70 degrees Celsius. Also, it is very important that the strain gauge laid on the temperature compensation can be applied *before* the can is emptied.

Everything else is simply a matter of preparation. For example, it should be realized that the hoop to longitudinal strain will not be the expected ratio. And it is recommended to use the hoop stress to derive all internal pressures.

As a final note, realize that these derived pressures are the amounts that exist while under the influence of our atmosphere. This means, of course, that they are about 14.7 psi (101.4 KPa) less than the absolute values that would actually exist.

VI. REFERENCES

1. Student's lab notebook, Ryan W. Livingston.
2. Student Manual for Strain Gage Technology, Bulletin 309C, Measurements Group, Inc., Raleigh, NC 1991.
3. Experimental Stress Analysis Notebook, Issue 13, Measurements Group, Inc., Raleigh, NC 1991.
4. Beckwith, Marangoni, and Lienhard. Mechanical Measurements. New York: Addison-Wesley Publishing Company Inc., 1993.
5. Physical Constants for Can/End Making Aluminum, Facsimile, Reynolds Metals Company.
6. Pop Can Aluminum Modulus of Elasticity, Janet Tichelaar, MECH 221, Winter 1997.

MECH 221 COURSE PROJECT: POP CAN PRESSURES
Janet Tichelaar and Ryan Livingston
Group #1
Winter 1997

Trial	ea	eb	ec	E		Poisson's Ratio (nu)	radius gmax/2	Mohr's Circle's Center	Microstrain HOOP e1	Microstrain LONG. e2
Left Alone	1573	658	261	68000	MPa	0.30	705	917	1622	212
Heated	1250	368	370	68000	MPa	0.30	624	810	1434	186
Shaken	76	8	69	68000	MPa	0.30	65	73	137	8
Shaken and Opened	859	391	329	68000	MPa	0.30	334	594	928	260

Modulus of Elasticity=	68,000	MPa
Ultimate Tensile Strength=	300	MPa
Yield Strength=	276	MPa

Thickness of Metal=	0.097	millimeters
Radius of Can=	33.058	millimeters

Left alone			Pressure (derived from hoop orientation)				
Hoop Stress =	125.971	MPa	367.72368	KPa	or	53.33	psi
Longitudinal Stress =	52.189	MPa					
Increase from heating 50 degrees Celsius							
Hoop Stress =	111.308	MPa	324.92081	KPa	or	47.13	psi
Longitudinal Stress =	46.063	MPa			+	53.33	psi
					TOTAL=	100.46	psi
Increase from shaking							
Hoop Stress =	10.422	MPa	30.42192	KPa	or	4.41	psi
Longitudinal Stress =	3.664	MPa			+	53.33	
					TOTAL=	57.75	psi
Shaken and opened							
Hoop Stress =	75.164	MPa	219.41167	KPa	or	31.82	psi
Longitudinal Stress =	40.242	MPa					
		UNSUCCESSFUL					

Rupture Pressure (derived from hoop orientation)
875.731 KPa or 127.014 psi

MECH 221 COURSE PROJECT: POP CAN PRESSURES; ERROR ANALYSIS

Ryan Livingston and Janet Tichelaar
Group #1
Winter 1997

Note that the parameters involved in the error analysis are:

***material thickness**
***can radius**
***modulus of elasticity**
***stress orientation**
***strain measurments**

Out of these parameters, multiple measurements were taken of:

***material thickness**
***can radius**
***modulus of elasticity**
***stress orientation**

NOTE: Modulus of elasticity error was determined in the second section of this project, entitled "Pop Can Aluminum Modulus of Elasticity".

Stress and Strain-related measurements were only taken once from each pressurized pop can situation.

Measured stress orientation was 9 degrees offset from perfect circumfrencial orientation.

DATA

Material Thickness	
0.09652	mm
0.09398	mm
0.09652	mm
0.09652	mm
0.09906	mm
$t_{v,a}$	2.7765
Sx	0.0018
average	0.0965

Can Radius	
33.057	mm
33.060	mm
33.055	mm
33.059	mm
33.059	mm
$t_{v,a}$	2.7765
Sx	0.0020
average	33.0580

FINAL ERROR ANALYSIS RESULT=

2.31%

ALUMINUM POP CAN
MODULUS OF ELASTICITY

by

Group #1
Ryan Livingston and Janet Tichelaar

Ferris State University

MECH 221
Mechanical Measurements with Computer Applications

April 21, 1997

MECH 221 MEASUREMENT OF THE MODULUS OF ELASTICITY

SUMMARY

The purpose of this experiment is to determine the modulus of elasticity of the alloy 3104 H-19 specimen taken from the cylinder wall of a *Coca-Cola Classic* can. This will be done with the use of strain gauge measurements, while the specimen is under known tensile stress.

We will be measuring the strain on a "dog-bone" shaped sample of the aluminum alloy 3104 H-19 that will be loaded in tension with known masses. This will provide the strain that will allow the determination of the modulus of elasticity.

$$\mathbf{E} = \frac{\sigma}{\varepsilon}$$

Where: E is the modulus of elasticity
σ is the stress (tension in our case)
ε is the strain (microstrain)

Since the strain will be recorded at variable mass values, a computer spreadsheet program will be used to find the average value of modulus of elasticity for the aluminum alloy. The values of slope, intercept, and correlation will also be determined using the spreadsheet to find the ideal value of the modulus of elasticity that corresponds to the experimental data.

MECH 221 ALUMINUM POP CAN MODULUS OF ELASTICITY

CONTENTS

MECH 221 ALUMINUM POP CAN MODULUS OF ELASTICITY

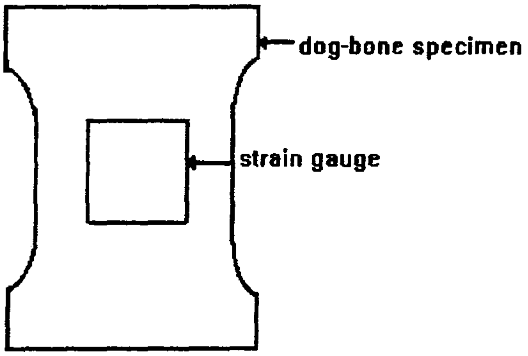
I. OBJECTIVE

The objective of this experiment is to measure the modulus of elasticity of an aluminum alloy 3104 H-19. This will be done with the use of a strain gauge, tensile stress computations, and the use of a spreadsheet program. The spreadsheet will aid in attainment of the modulus of elasticity. The value of the slope (or otherwise known as the modulus of elasticity) will be found from the regression fit of the experimental data.

II. APPARATUS

As shown in the following diagram, the apparatus consists of the following components:

1. C-clamps
2. Aluminum "dog-bone" specimen (approx. 1/2 inches wide and .0038 inches thick)
3. Strain gauge suitable for aluminum
4. Strain gauge application kit and supplies
5. Temperature-controlled soldering iron and soldering supplies.
6. Vernier Caliper
7. Engineering scale
8. Set of precision gram masses
9. Wheatstone bridge completion circuit and strain indicator
10. Metal Hanger (not shown)
11. Balance Scale



III. PROCEDURE

1. Measure and record the dimensions of the "dog-bone" specimen provided.
2. Prepare the specimen for attaching the strain gage.
3. Burnish marks at the pre-determined locations for purpose of installing the strain gauge.
4. Install the gauge according to the instructions provided in the Student Manual for Strain Gauge Technology and attach lead wires.
5. Clamp the specimen in the C-clamps to assure a firm hold and attach to the testing table.
6. Attach lead wires to strain indicator using a quarter bridge configuration.
7. Create a known and uniform tensile force by applying precision gram masses to the hanger (which is attached to the bottom of the specimen).
8. Record the strain, as shown on the strain indicator, and the corresponding mass making up the load.
9. Repeat the procedure with combinations of loads until a statistically significant quantity of data had been collected.

IV. DATA REDUCTION, SAMPLE CALCULATIONS, AND STATISTICS

All recorded data and derived statistics are given on the attached spreadsheet, entitled "Modulus of Elasticity."

To calculate the stress applied the following equation was used:

$$\sigma = \frac{force}{area}$$

*The force is derived as the amount of mass times the value of the acceleration of gravity.

For example: 1142 grams *9.81 meters/second^2=11.20302 Newtons

*The area is derived as the width times the thickness of the test specimen.

For example: .0125 meters * 9.653 E-5 meters=1.22 E-06 meters^2

The stress is therefore equal to:

11.20302 Newtons/1.22 E-06 meters^2=9,213,028 Newtons/meters^2

The modulus of elasticity is equal to the amount of stress at a given mass divided by the corresponding strain.

For example:
(9,213,028 Newtons/meters^2)/(197 E-06 strain)=46.8 Giga Pascal.

From the collective information gathered, the spreadsheet program was used to determine the least squares fit (a regression line). In essence, the slope of the regression line is the basic definition of the modulus of elasticity. More specifically, where the slope is "rise over run," the modulus of elasticity is stress divided by strain.

V. RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Results from the regression line, the slope provided us with a final modulus of elasticity of **68 GPa**. The published value for an aluminum alloy is 77 GPa. The difference in value is attributed to the work hardening of the metal. This work hardening takes place during the period when the can is fabricated. Reynold's Metals stated the value to be 69 GPa after the can is formed.

Another reason for variation in the modulus of elasticity is due to the measurement of the thickness of the specimen. The published value from Reynolds Metals is .0039 inches or 9.906 E-05 meters. The value obtained from measurement of the test specimen used was determined to be .0038 inches or 9.652 E-05 meters. Reynolds Metals also cited there is a .0002 inch combined coating on the inside and outside of the aluminum specimen that also must be taken into consideration (this value was subtracted from the value of .0040 to attain the .0038 inch reading for thickness).

The strain gauge that was attached to the specimen also has an effect on the materials property. The strain gauge would cause a decrease in the modulus of elasticity. The decrease in the modulus of elasticity would be due to the increase in area of the specimen (which directly causes a decrease in the stress).

The last possibility for error is due to stress risers that were created while forming the test specimen. The specimen is a very thin strip of aluminum that is very sensitive to any shaping or bending that it may undergo.

The equipment and methods used in this experiment seemed to be as practicable as possible. The only recommendations that we would suggest would be a larger cross sectional area to provide a more stable specimen and a better apparatus for applying the precision masses. Any way to improve the accuracy of the experiment would provide more exact results.

VI. REFERENCES

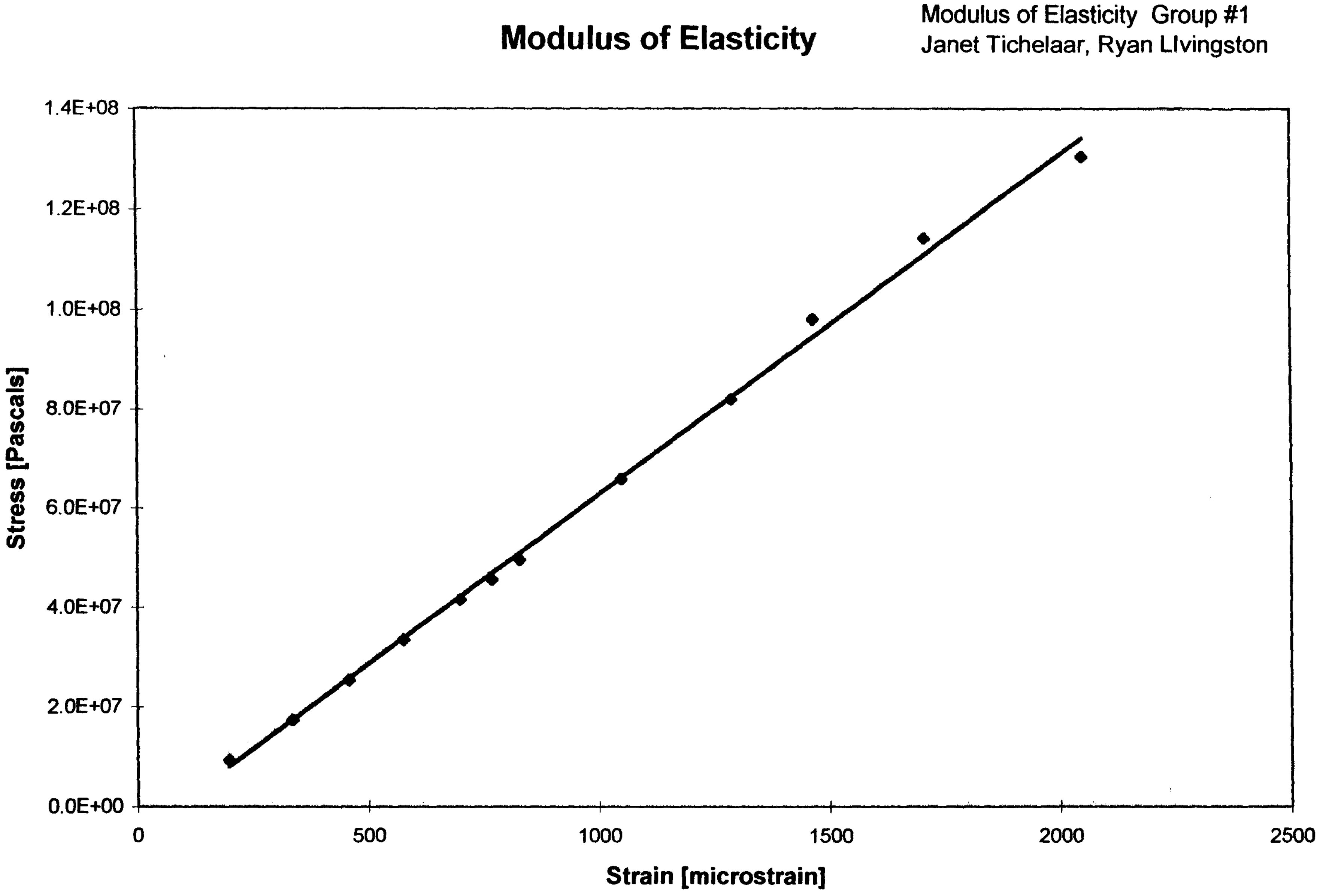
1. Wolf, Lawrence J. Statics and Strengths of Materials, A parallel approach to understanding structures. Columbus, Merril Publishing Company.
2. Student's lab notebook, Ryan W. Livingston; page 30
3. Student Manual for Strain Gage Technology, Bulletin 309C, Measurements Group, Inc., Raleigh, NC 1991.
4. William Forsyth, Reynolds Metals. Personal Interview. April 15, 1997.

PROJECT B--MODULUS OF ELASTICITY					area=b*h		slope=	68008.549
GROUP # 1 RYAN LIVINGSTON AND JANET TICHELAAR					in2	m2	intercept=	-5400350.6
12-Apr-97					0.0018848	1.216E-06	correlation=	0.9986791
							Regression	
STRAIN	MASS	FORCE	STRESS	MOD. OF ELASTICITY			Stress	
[microstrain]	[grams]	N	[N/m2]	GPa			[N/m^2]	
197	1142	11.20302	9213028	4.68E+10			7997333.613	
334	2142	21.01302	17280479	5.17E+10			17314504.85	
457	3142	30.82302	25347929	5.55E+10			25679556.39	
575	4142	40.63302	33415379	5.81E+10			33704565.19	
698	5142	50.44302	41482830	5.94E+10			42069616.74	
767	5642	55.34802	45516555	5.93E+10			46762206.63	
827	6142	60.25302	49550280	5.99E+10			50842719.58	
1049	8142	79.87302	65685181	6.26E+10			65940617.49	
1288	10142	99.49302	81820081	6.35E+10			82194660.74	
1466	12142	119.113	97954982	6.68E+10			94300182.49	
1708	14142	138.733	1.14E+08	6.68E+10			110758251.4	
2050	16142	158.353	1.3E+08	6.35E+10			134017175.2	
2550	17730	173.9264	1.43E+08	5.61E+10	outside the elastic limit		168021449.8	
2787	19730	193.5464	1.59E+08	5.71E+10			184139475.9	
3180	22030	216.1094	1.78E+08	5.59E+10			210866835.7	
3247	22490	220.6269	1.81E+08	5.59E+10			215423408.5	
3290	22951	225.1444	1.85E+08	5.63E+10			218347776.1	
			average	5.95046576E+10				
					MODULUS OF ELASTICITY IS EQUAL TO THE SLOPE:			
						E=	68 GPa	

Mechanical Engineering Technology

Student Projects
1997-1998

Section 2 of 3



Modulus of Elasticity

Modulus of Elasticity Group #1
Janet Tichelaar, Ryan LIvingston

MECH 221 COURSE PROJECT: MODULUS OF ELASTICITY; ERROR ANALYSIS
RYAN LIVINGSTON and JANET TICHELAAR
Group #1
Winter 1997

Note the following parameters are involved in the error analysis:
*material thickness
*width of specimen
*strain
*load

Out of these parameters, multiple measurements were taken of:
*material thickness
*width of specimen

FINAL ERROR ANALYSIS RESULT=
2.30%

Material Thickness	
0.09652	mm
0.09398	mm
0.09652	mm
0.09652	mm
0.09906	mm
$t_{v,a}$	2.7765
Sx	0.0018
average	0.0965

Width of Specimen	
12.573	mm
12.5984	mm
12.5984	mm
12.6238	mm
12.5984	mm
$t_{v,a}$	2.7765
Sx	0.01796
average	12.5984

ERROR ANALYSIS

Note the following parameters are involved in the error analysis:
*material thickness (t)
*width of specimen (b)
*strain (e)
*load (p)

$$\mathrm{E} = \frac{\sigma}{\varepsilon} = \frac{P}{tb\varepsilon}$$

$$\frac{\Delta E}{\overline{E}} = \sqrt{\left(\frac{\Delta P}{\overline{P}}\right)^2 + \left(\frac{\Delta b}{\overline{b}}\right)^2 + \left(\frac{\Delta t}{\overline{t}}\right)^2 + \left(\frac{\Delta \varepsilon}{\overline{\varepsilon}}\right)^2}$$

$$.023 = \sqrt{\left(\frac{1}{10000}\right)^2 + \left(\frac{2.7765*.0018/\sqrt{5}}{.0965}\right)^2 + \left(\frac{2.7765*.001796/\sqrt{5}}{12.5984}\right)^2 + \left(\frac{2}{1200}\right)^2}$$

The error analysis is 2.3% at a 95% confidence level.

Effect of Pressure on the Direction of the Principal Strain Axes on the Surface of an Aluminum Can

by

Chris Clarke
Tom Morden

Students at Ferris State University
Mech 221
Mechanical Measurements with Computer Applications

April 21, 1997

MECH 221 PRESSUREIZED BEER CAN

Summary

In this experiment we mounted a Rosette on the side of a 25 0z. Aluminum beer can. The can was plumbed into an air pressure supply. We increased and decreased the pressure inside the can and measured the strains. We took 30 sets of strain measurements. We calibrated the pressure gage used to measure the pressure inside the can employing a Dead Weight Pressure tester. We found the pressure gage calibration data to have a correlation coefficient equal to 0.999503. The scatter about the regression line was 3.2% of the variation in indicated pressure. We used the corrected pressure for the graph of principal axis angle versus pressure. As the pressure was increased from 0 to 30 psi the inclination angle to the principal axis changed from about -2.0 degrees to +1.0 degrees.

MECH 221 PRESSURIZED BEER CAN

CONTENTS

MECH 221 PRESSURIZED BEER CAN

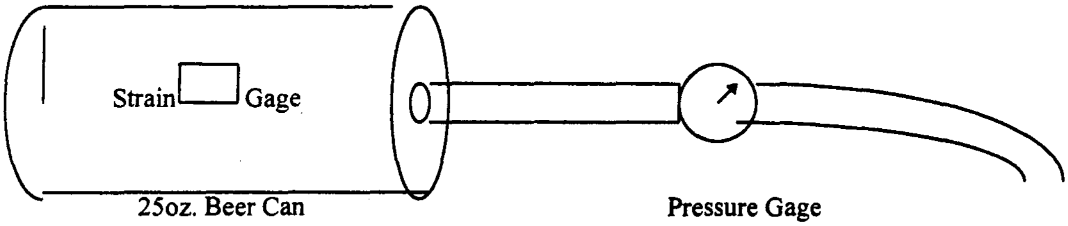
I. OBJECTIVE

The purpose of this experiment is to measure the strain on a aluminum beer can and be able to calculate Mohr's circle of strain using the data collected. A Rossette strain gage will be used to obtain the stresses placed on the aluminum can by each of the calibrated pressures. The Rossette gage is built with three strain gages to determine the reaction of the aluminum can in different areas of strain. The can will be pressurized with different pressures and the strains from each gage will be recorded.

II. APPARATUS

The equipment , supplies and apparatus necessary to perform this experiment include the following:

1. Calibrated pressure gage
2. Aluminum beer can, 25 oz.
3. Rosette Strain gauge suitable for aluminum
4. Strain gauge application kit and supplies
5. Temperature-controlled soldering iron and soldering supplies
6. Micrometer with vernier scale
7. Engineering scale
8. Pressure hoses and easy disconnect couplers
9. Wheatstone bridge completion circuit and strain indicator



III. CALCULATIONS

Principal Strains

Max shear strain:

$$1/2\gamma_{max} = 1/2(2(\varepsilon_a - \varepsilon_b)2 + 2(\varepsilon_b - \varepsilon_c)2)^{1/2}$$

Normal strains:

$$\varepsilon_{1,2} = (1/2)(\varepsilon_a + \varepsilon_c) +- (1/2)\,\gamma_{max}$$

MECH 221 PRESSURIZED BEER CAN

Principal Stresses

Max shear stress:

$$t_{max} = E/[2(1 + \nu)](2(\varepsilon_a-\varepsilon_b)^2 + 2(\varepsilon_b-\varepsilon_c)^2)^{1/2}$$

Principle stresses:

$$\sigma_{1,2}= (E/2)(\varepsilon_a + \varepsilon_c/(1 - \nu)) +- t_{max}$$

$$\tan 2\theta= (2\varepsilon_b- \varepsilon_a- \varepsilon_c)/(\varepsilon_a- \varepsilon_c)$$

$$0< \theta< 90°$$

$$\varepsilon_b > (\varepsilon_a + \varepsilon_c)/2$$

θ is measured ccw from the
a-axis of the algebraically
larger stress

IV. EXPERIMENTAL PROCEDURE

The method of approach for finding the Mohr's circle of strain of an aluminum can begins with following these steps:

1. Prepare a data sheet in your science laboratory notebook,

2. Prepare the aluminum can for attaching the strain gage,

3. Place burnish marks along and perpendicular to the centerline of the can for mounting the strain gage,

4. Select and install the gage according to the instructions outlined in the Student Manual for Strain Gage Technology (Reference 1),

5. Install the pressure line to the center of the bottom of the can,

6. Surround the opening on the top and the hose inlet on the bottom of the can with m-coat A,

7. Connect the three gage leads to the strain indicator system in a quarter-bridge circuit,

8. Begin to pressurize the can with known pressures by use of a pressure gage and record the strains to your notebook in columns strain 1, strain 2, and strain 3,

9. Repeat the procedure with combinations of pressures until a statistically significant amount of data has been obtained.

V. ANALYSIS AND PRESENTATION OF DATA

The data has been reduced into a spreadsheet template. The following steps were taken in reducing and presenting the data include the following:

1. Enter the data obtained from the experiment into the spreadsheet,
2. Determine the expected normal strain, and the shear strain from the equations shown in the Calculations,
3. Graph the values of pressure indicated, and the actual applied pressure,
4. Graph the values of the actual applied pressure versus the value of theta,
5. Graph the data of the normal strain versus the shear strain.

VI. RESULTS AND CONCLUSIONS

The result for Mohr's Circle of Strain of the aluminum can is found from the graph and the associated statistics. It is also important to establish an estimate of the measurement error expected.

1. Determine mohr's circle of strain for the aluminum can to be the slope of the linear regression line through graph of the data and note the correlation coefficient,

2. Compare the results of the applied pressure to the indicated pressure of the gage,

3. Estimate the magnitude of experimental error and identify the expected error level for each independent component of the measurement process.

VII. REFERENCES

1. Student Manual for Strain Gage Technology, Bulletin 309D, Measurements Group, Inc., Raleigh, NC 1991.
2. SB-10 Switch and Balance Unit Manual, Measurements Group, Inc., Raleigh, NC.

3. P-3500 Strain Indicator Manual, Measurements Group, Inc., Raliegh, NC.

4. Wolf, Lawrence J., Statics and Strengths of Materials: A Parallel Approach to Understanding Structures. Mereill Publishing Company, Columbus, 1988. Pages 276-280 and 338-339.

5. Bechwith, Thomas G., Marangoni, Roy D., and Lienhard, John H.: Mechanical Measurements with Computer Applications, Addison-Wesly Publishing Company, Reading, MA, Fifth Edition, 1993. Chapters 3 and 12.

7. Microsoft Excel

MOHR'S SPREADSHEET

PROJECT PROPOSAL A: PRESSUREIZED POP CAN
MECH 221 Mechanical Measurements with Computer Applications
Group #6
2/2/97
TEMP: Before 20°C
After: 20°C

TOM MORDEN
CHRIS CLARKE

a= 2.74337
b= 0.97662

	Indicated	Pressure				(psi)					(psi)	(psi)	(psi)	2*theta	condition	degr	degr
0	0	0	0	0	0	1.04E+07	0.32	0	0	0	0	0	0	0	0	0	0
1	5	2.31	-69	-38	-11	1.04E+07	0.32	29	-11	-69	2.29E+08	-3.83E+08	-8.41E+08	-0.069	1	-3.95	-1.97
2	10	7.43	-112	-62	-14	1.04E+07	0.32	49	-14	-112	3.86E+08	-5.77E+08	-1.35E+09	-0.020	1	-1.17	-0.58
3	15	12.55	-142	-75	-12	1.04E+07	0.32	65	-12	-142	5.12E+08	-6.65E+08	-1.69E+09	-0.031	1	-1.76	-0.88
4	20	17.67	-155	-77	-5	1.04E+07	0.32	75	-5	-155	5.91E+08	-6.32E+08	-1.81E+09	-0.040	1	-2.29	-1.15
5	25	22.79	-160	-74	1	1.04E+07	0.32	81	1	-160	6.36E+08	-5.80E+08	-1.85E+09	-0.068	1	-3.91	-1.95
6	30	27.91	-160	-70	9	1.04E+07	0.32	85	9	-160	6.67E+08	-4.88E+08	-1.82E+09	-0.065	1	-3.72	-1.86
7	25	22.79	-156	-70	7	1.04E+07	0.32	82	7	-156	6.43E+08	-4.96E+08	-1.78E+09	-0.055	1	-3.16	-1.58
8	20	17.67	-147	-68	6	1.04E+07	0.32	77	6	-147	6.03E+08	-4.75E+08	-1.68E+09	-0.033	1	-1.87	-0.94
9	15	12.55	-129	-62	4	1.04E+07	0.32	67	4	-129	5.24E+08	-4.32E+08	-1.48E+09	-0.008	1	-0.43	-0.22
10	10	7.43	-103	-50	0	1.04E+07	0.32	52	0	-103	4.06E+08	-3.82E+08	-1.19E+09	-0.029	1	-1.67	-0.83
11	5	2.31	-58	-28	-1	1.04E+07	0.32	29	-1	-58	2.25E+08	-2.26E+08	-6.76E+08	-0.053	1	-3.01	-1.51
12	10	7.43	-114	-67	-13	1.04E+07	0.32	51	-13	-114	3.99E+08	-5.72E+08	-1.37E+09	0.069	-1	3.96	1.98
13	15	12.55	-145	-80	-11	1.04E+07	0.32	67	-11	-145	5.28E+08	-6.65E+08	-1.72E+09	0.030	-1	1.71	0.85
14	20	17.67	-159	-81	-4	1.04E+07	0.32	78	-4	-159	6.11E+08	-6.36E+08	-1.86E+09	-0.006	1	-0.37	-0.18
15	25	22.79	-163	-77	3	1.04E+07	0.32	83	3	-163	6.54E+08	-5.69E+08	-1.88E+09	-0.036	1	-2.07	-1.04
16	30	27.91	-161	-71	12	1.04E+07	0.32	87	12	-161	6.82E+08	-4.57E+08	-1.82E+09	-0.040	1	-2.32	-1.16
17	25	22.79	-158	-72	10	1.04E+07	0.32	84	10	-158	6.62E+08	-4.70E+08	-1.79E+09	-0.024	1	-1.36	-0.68
18	20	17.67	-148	-69	8	1.04E+07	0.32	78	8	-148	6.15E+08	-4.56E+08	-1.69E+09	-0.013	1	-0.73	-0.37
19	15	12.55	-132	-64	3	1.04E+07	0.32	68	3	-132	5.32E+08	-4.55E+08	-1.52E+09	-0.007	1	-0.42	-0.21
20	10	7.43	-106	-53	1	1.04E+07	0.32	54	1	-106	4.22E+08	-3.81E+08	-1.22E+09	0.009	-1	0.54	0.27

MOHR'S SPREADSHEET

$a =$ -2.4264
$b =$ 0.11424
$r =$ 0.92456
$r2 =$ 0.85482

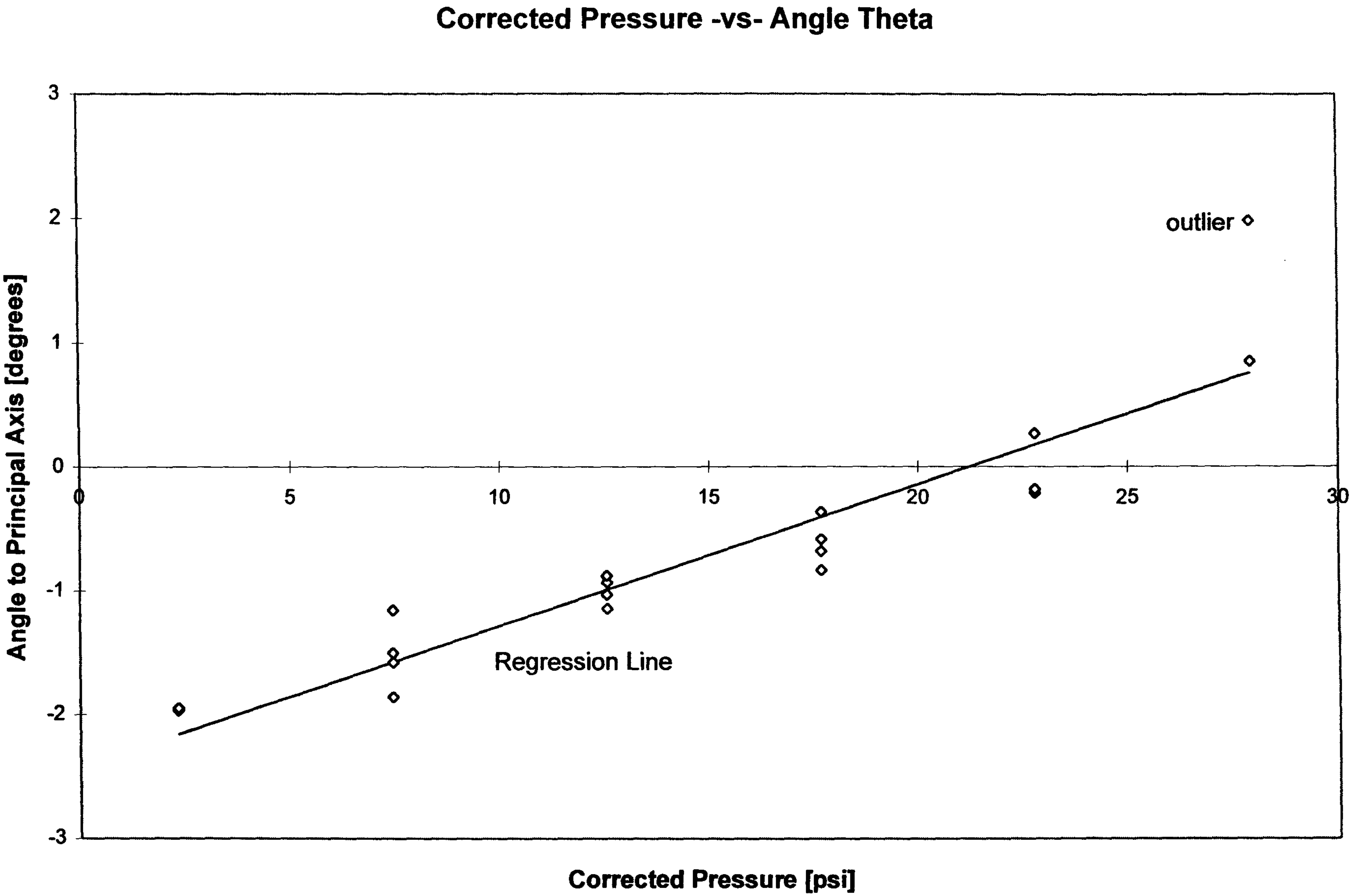
$\text{theta}_{measured} =$ 0
$\text{theta}_{AVG} =$ -0.64
$S_{theta} =$ 0.665811

delta= 5
center= -64

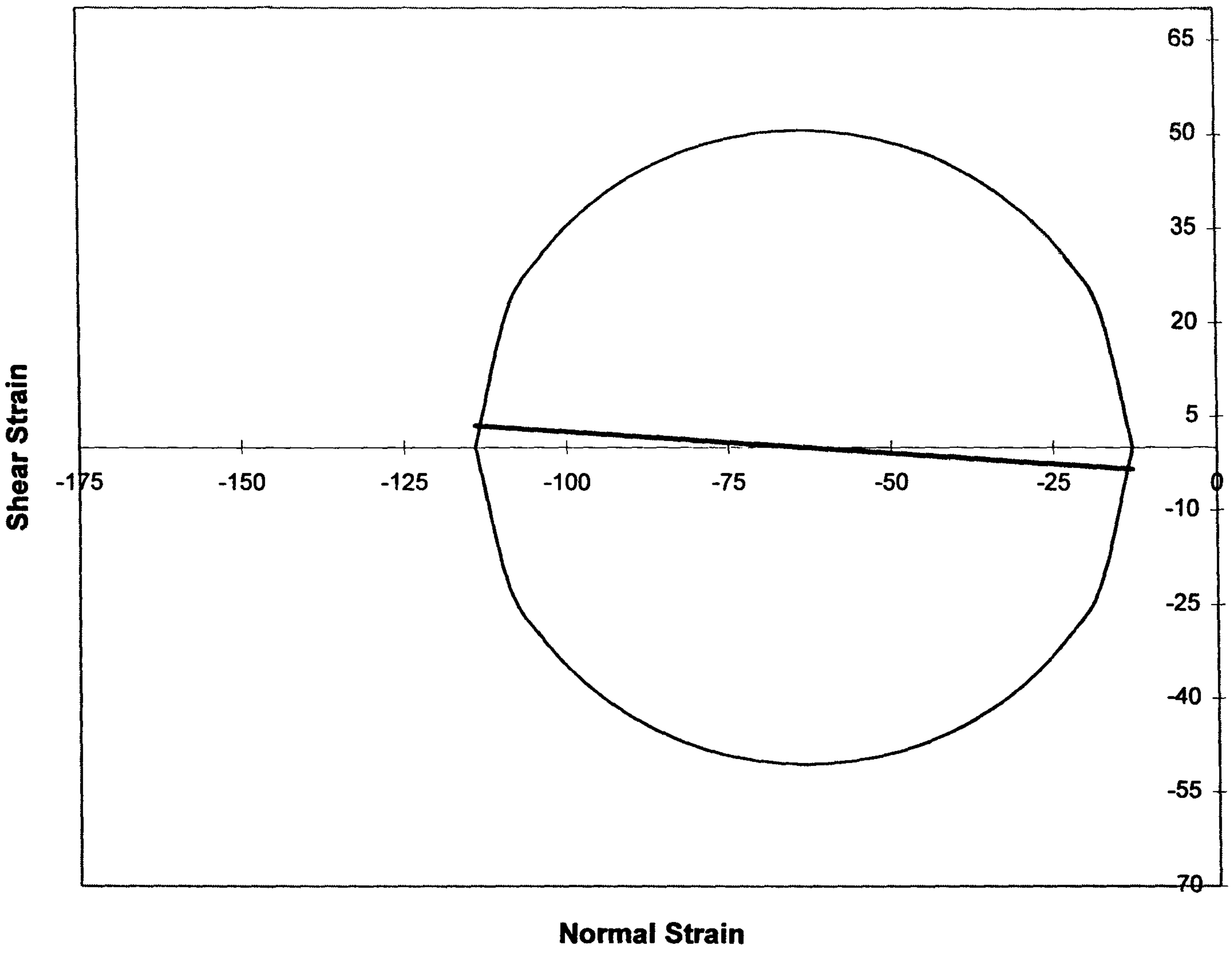
No.	e	y_1	y_2	y_{line}
1	-114	0	0	3.49
2	-109	22.0652	-22.0652	3.14
3	-104	30.3727	-30.3727	2.79
4	-99	36.1507	-36.1507	2.44
5	-94	40.4969	-40.4969	2.09
6	-89	43.8392	-43.8392	1.75
7	-84	46.395	-46.395	1.40
8	-79	48.2895	-48.2895	1.05
9	-74	49.5984	-49.5984	0.70
10	-69	50.3674	-50.3674	0.35
11	-64	50.6211	-50.6211	0.00
12	-58	50.3674	-50.3674	-0.35
13	-53	49.5984	-49.5984	-0.70
14	-48	48.2895	-48.2895	-1.05
15	-43	46.395	-46.395	-1.40
16	-38	43.8392	-43.8392	-1.75
17	-33	40.4969	-40.4969	-2.09
18	-28	36.1507	-36.1507	-2.44
19	-23	30.3727	-30.3727	-2.79
20	-18	22.0652	-22.0652	-3.14
21	-13	0	0	-3.49

Graph Block

Pressure (psi)	Theta (degrees)	Regression Line	
2.311	-1.973	-2.162486	
2.311	-1.954	-2.162486	
7.430	-1.862	-1.577628	
7.430	-1.580	-1.577628	
7.430	-1.506	-1.577628	
7.430	-1.159	-1.577628	
12.550	-1.145	-0.99277	
12.550	-1.035	-0.99277	
12.550	-0.936	-0.99277	
12.550	-0.881	-0.99277	
17.670	-0.834	-0.407911	
17.670	-0.682	-0.407911	
17.670	-0.585	-0.407911	
17.670	-0.367	-0.407911	
22.789	-0.215	0.176947	
22.789	-0.212	0.176947	
22.789	-0.185	0.176947	
22.789	0.268	0.176947	
27.909	0.855	0.761806	
27.909	1.982	0.761806	outlier


Corrected Pressure -vs- Angle Theta
Angle to Principal Axis [degrees]
3
2
1
0
-1
-2
-3
0
5
10
15
20
25
30
outlier
Regression Line
Corrected Pressure [psi]

MOHR'S CIRCLE OF STRAIN

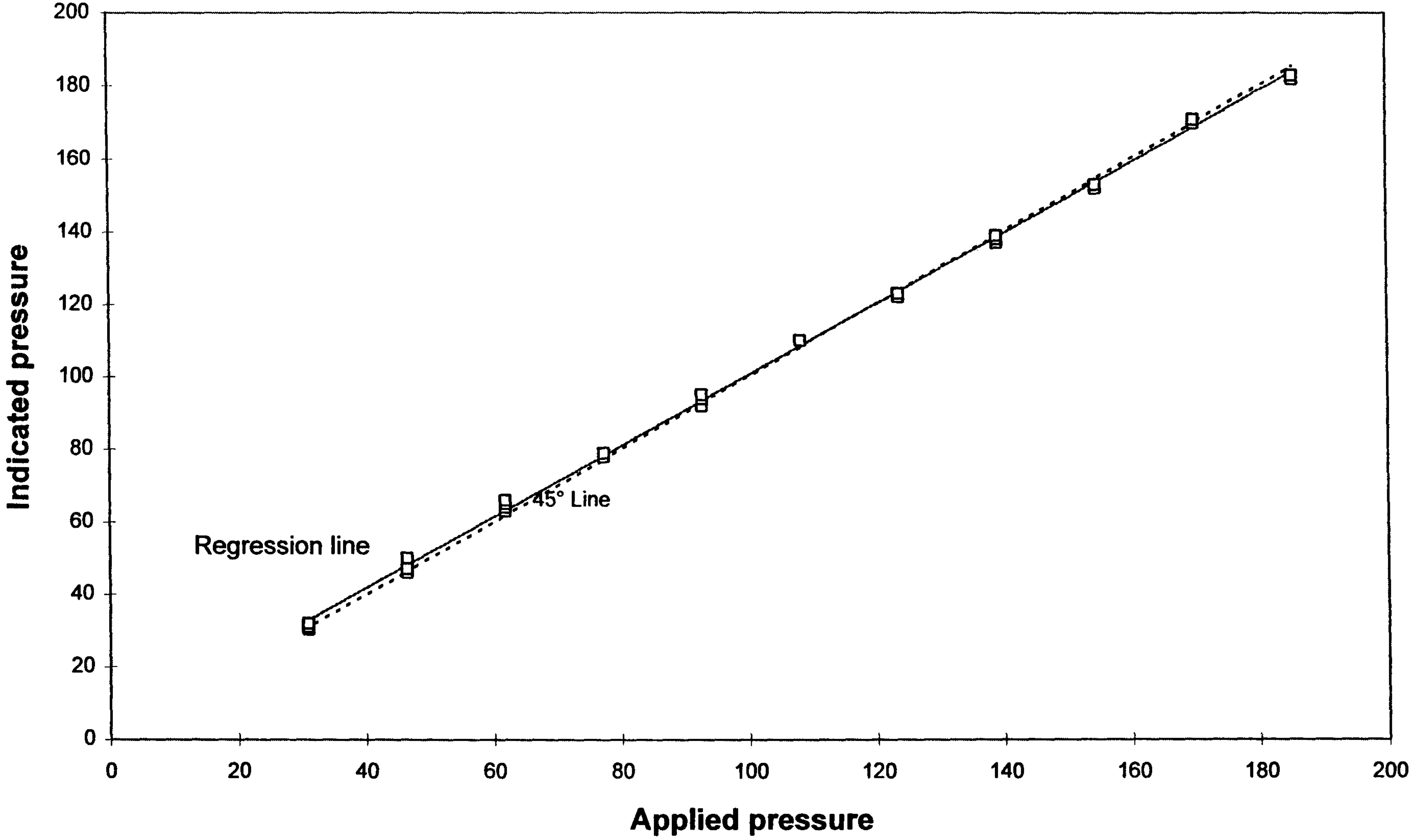


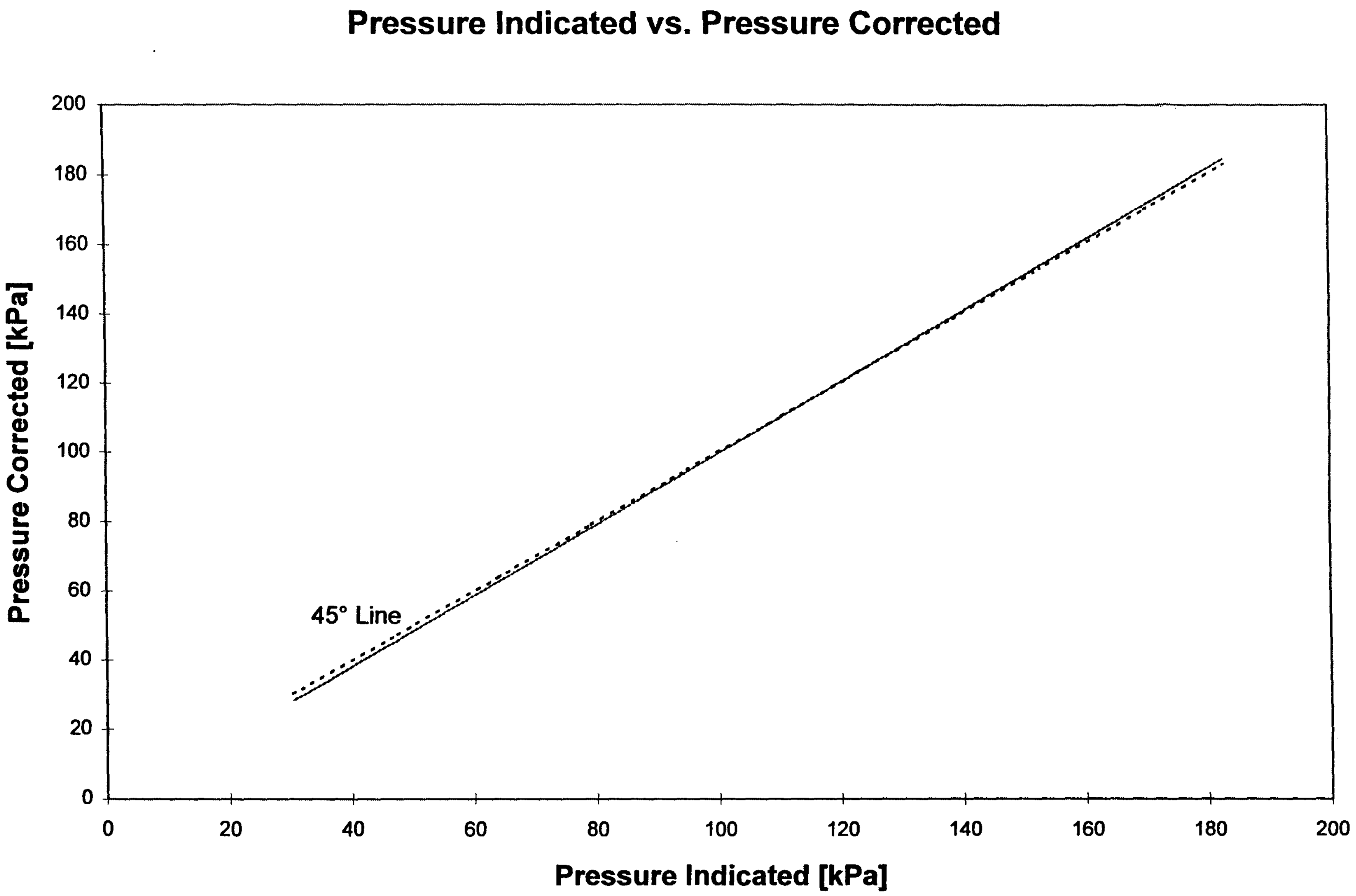
PROJECT A: PRESSUREIZED POP CAN EXPERIMENT				
GROUP # 6		Tom Morden	a=	2.743373
4/15/97		Chris Clarke	b=	0.976624
TEMP:	BEFORE: 20°C		r=	0.999503
	AFTER: 20°C		r2=	0.999007
			scatter=	0.099339

Trial #	Indicated Reading (kn/m2)	Mass kg	Applied pressure (kn/m2)	Indicated	Applied
1	30.3	1.0	30.906	30.3	30.906
2	46	1.5	46.358	31	30.906
3	65	2.0	61.811	32	30.906
4	79	2.5	77.264	46	46.358
5	94	3.0	92.717	47	46.358
6	110	3.5	108.170	47	46.358
7	122	4.0	123.622	50	46.358
8	138	4.5	139.075	63	61.811
9	153	5.0	154.528	64	61.811
10	170	5.5	169.981	65	61.811
11	183	6.0	185.433	66	61.811
12	171	5.5	169.981	78	77.264
13	153	5.0	154.528	79	77.264
14	138	4.5	139.075	79	77.264
15	122	4.0	123.622	79	77.264
16	110	3.5	108.170	92	92.717
17	94	3.0	92.717	94	92.717
18	78	2.5	77.264	94	92.717
19	64	2.0	61.811	95	92.717
20	47	1.5	46.358	110	108.170
21	32	1.0	30.906	110	108.170
22	47	1.5	46.358	110	108.170
23	63	2.0	61.811	110	108.170
24	79	2.5	77.264	122	123.622
25	95	3.0	92.717	122	123.622
26	110	3.5	108.170	122	123.622
27	122	4.0	123.622	123	123.622
28	139	4.5	139.075	137	139.075
29	152	5.0	154.528	138	139.075
30	170	5.5	169.981	138	139.075
31	182	6.0	185.433	139	139.075
32	170	5.5	169.981	152	154.528
33	152	5.0	154.528	152	154.528
34	137	4.5	139.075	153	154.528
35	123	4.0	123.622	153	154.528
36	110	3.5	108.170	170	169.981
37	92	3.0	92.717	170	169.981
38	79	2.5	77.264	170	169.981
39	66	2.0	61.811	171	169.981
40	50	1.5	46.358	182	185.433
41	31	1.0	30.906	183	185.433

Graph Block							
x applied pressure	y1 indicated pressure	y2 regression line	y3 45° line	y1 corrected pressure	x indicated pressure	y2 indicated pressure	Corrected Pressure (psi)
30.906	30.3	32.92651	30.90558	28.21621	30.3	30.3	4.09242
30.906	31	32.92651	30.90558	28.93296	31	31	4.19637
30.906	32	32.92651	30.90558	29.9569	32	32	4.34488
46.358	46	48.01807	46.35837	44.292	46	46	6.42401
46.358	47	48.01807	46.35837	45.31593	47	47	6.57252
46.358	47	48.01807	46.35837	45.31593	47	47	6.57252
46.358	50	48.01807	46.35837	48.38774	50	50	7.01805
61.811	63	63.10964	61.81116	61.6989	63	63	8.94867
61.811	64	63.10964	61.81116	62.72284	64	64	9.09718
61.811	65	63.10964	61.81116	63.74677	65	65	9.24569
61.811	66	63.10964	61.81116	64.77071	66	66	9.39420
77.264	78	78.2012	77.26395	77.05793	78	78	11.17631
77.264	79	78.2012	77.26395	78.08187	79	79	11.32482
77.264	79	78.2012	77.26395	78.08187	79	79	11.32482
77.264	79	78.2012	77.26395	78.08187	79	79	11.32482
92.717	92	93.29277	92.71674	91.39303	92	92	13.25544
92.717	94	93.29277	92.71674	93.4409	94	94	13.55246
92.717	94	93.29277	92.71674	93.4409	94	94	13.55246
92.717	95	93.29277	92.71674	94.46484	95	95	13.70097
108.170	110	108.3843	108.1695	109.8239	110	110	15.92861
108.170	110	108.3843	108.1695	109.8239	110	110	15.92861
108.170	110	108.3843	108.1695	109.8239	110	110	15.92861
108.170	110	108.3843	108.1695	109.8239	110	110	15.92861
123.622	122	123.4759	123.6223	122.1111	122	122	17.71072
123.622	122	123.4759	123.6223	122.1111	122	122	17.71072
123.622	122	123.4759	123.6223	122.1111	122	122	17.71072
123.622	123	123.4759	123.6223	123.135	123	123	17.85923
139.075	137	138.5675	139.0751	137.4701	137	137	19.93836
139.075	138	138.5675	139.0751	138.4941	138	138	20.08687
139.075	138	138.5675	139.0751	138.4941	138	138	20.08687
139.075	139	138.5675	139.0751	139.518	139	139	20.23537
154.528	152	153.659	154.5279	152.8292	152	152	22.16600
154.528	152	153.659	154.5279	152.8292	152	152	22.16600
154.528	153	153.659	154.5279	153.8531	153	153	22.31450
154.528	153	153.659	154.5279	153.8531	153	153	22.31450
169.981	170	168.7506	169.9807	171.26	170	170	24.83916
169.981	170	168.7506	169.9807	171.26	170	170	24.83916
169.981	170	168.7506	169.9807	171.26	170	170	24.83916
169.981	171	168.7506	169.9807	172.2839	171	171	24.98767
185.433	182	183.8422	185.4335	183.5472	182	182	26.62127
185.433	183	183.8422	185.4335	184.5712	183	183	26.76978

Graph of Applied pressure vs. Indicated pressure.




Pressure Indicated vs. Pressure Corrected
Pressure Corrected [kPa]
200
180
160
140
120
100
80
60
40
20
0
45° Line
0
20
40
60
80
100
120
140
160
180
200
Pressure Indicated [kPa]

APPENDIX A

Experiment: Pressurized Aluminum Beer Can

Group # 6

Chris Clarke

Tom Morden

We inserted this appendix to show that all the strains involved were proportional to eachother. We could verify this by measureing the strains when the pressure in the can was increased from 0 to 30 psig and then the pressure was removed and it again settled at 0 psig. The measured strains that we recorded do indicate that the Principal strain is proportional when the pressure is adjusted. We then repeated the test using 20 psig.

							Principal Strain
				From earlier calculations			-160
			Rosette				-155
Trial #	Pressure psig	strain a e-6	strain b e-6	strain c e-6			
1	30-0	156	69	-8	% error		
2	0-30	-158	-73	8	1.25		
3	20-0	147	75	2	% error		
4	0-20	-156	-80	-5	5.81		

Calibration and Measurement of a Torque Arm

MECH 221
Mechanical Measurements with Computer Applications

Mechanical Engineering Technology Program
Ferris State University

April 16, 1997

by

Tom Morden
Chris Clarke

MECH 221 CALIBRATION AND MEASUREMENT OF A TORQUE ARM

SUMMARY

Our given torque arm was calibrated using a strain gage. The torque was measured in inch-pounds. We used a calibrated torque meter in this experiment. It wasn't off by much. The strain gage was hooked up to the SP-10 and correct equipment. The gage factor was then set so the torque meter read 10 inch-pounds, the reading on the SP-10 was 100. The following was observed:

Slope = .86

Correlation = .999909

Percent Scatter = 1.35

All but 1.35% of our data was explained by the regression line.

MECH 221 CALIBRATION AND MEASUREMENT OF A TORQUE ARM

CONTENTS

MECH 221 CALIBRATION AND MEASUREMENT OF A TORQUE ARM

I OBJECTIVE

he applied torque ofs experiment was to calibrate and compare the output torque of a torque wrench and the strain of a strain gage. The strain gage was mounted on a 2.5 inch extension in order to measure the applied torque of the wrench. We then compared the calculated torque versus the indicated torque of the torque wrench. We also used the readings from the gage as a torque meter to take the place of the torque wrench.

II APPARATUS

We measured the Torque by means of strain gages aligned at a 22.5° angle with the longitudinal axis. Figure 1 depicts a typical arrangement. Note that gages 1 and 2 are at a 45° angle to eachother.

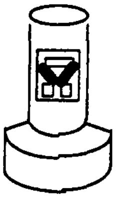


Figure 1. Strain Gage Arrangement for measurement of a torque arm.

The Equipment and supplies needed for this experiment include:

1. 3/8" drive extension,
2. Torque wrench (readings in in-lbs. preferred),
3. Metal strain gages(2),
4. Wheatstone bridge completion circuits (SB-10).
5. Strain indicator (MM P-3500).
6. Strain gage application materials, supplies and tools.

III PROCEDURE

Install each strain gage. After installing the strain gages hook up the SP-10 in a quarter-bridge circuit. Employ the "three-wire" method to achieve lead wire resistance compensation. After hooking up the SP-10 and the control box zero amps and etc. Then turn the gage factor so it reads 100 micro-strain for every 10 in.-lbs. You are then ready to take readings. Build a spreadsheet finding the calculated torque. Then construct a graph of Input Torque -vs- Calculated torque.

IV EXPERIMENTAL OBSERVATIONS

The output of the strain indicator held to a steady increment of 0.000 micro-strain sometimes off by 1-3 micro-strain. We corrected this by resetting the indicator to 0.000 micro-strain. The offsetting could have been caused by using a different gage factor other than classified to make the torque arm read accurately.

V CALCULATIONS

The calibration of the torque arm data was found by using an excel spreadsheet. We used the slope, correlation, and the intercept functions. We found the torque by using the following equation:

$$T=(GJ/R)*\text{strain indicated}$$

$J = (\pi D^4/32)$
$G = (E/(2*(1+\gamma)$
$E = 30E6$
$\gamma = .28$
$R = \text{radius}$

VI RESULTS AND CONCLUSIONS

The results of this experiment were that the data taken were very close to the regression line made. The data taken was indeed satisfactory.

VII REFERENCES

1. Microsoft Excel
2. Mechanical Measurement with Computer Applications Textbook.
3. Strain Gauge Application Manual.

Experiment 8: Calibration and Measurement of a Torque Arm

Chris Clarke

Tom Morden

4/16/97

calc. T= (GJ/R)strain

Group #6

Temp: Before= 23°C

After= 23°C

E (psi)=	3.00E+07
J (in4)=	0.002295
G (psi)=	11718750

Trail #	Input Torque (in-lbs)	Strain e-6	Calculated Torque (in-lbs)	% Error	Diameter (inches)
1	5	50	5.78	-15.67	0.466
2	10	102	11.80	-17.98	0.465
3	15	154	17.81	-18.75	0.464
4	20	204	23.60	-17.98	0.465
5	15	152	17.58	-17.21	0.465
6	10	100	11.57	-15.67	0.465
7	5	50	5.78	-15.67	0.465
8	10	97	11.22	-12.20	0.463
9	15	147	17.00	-13.35	0.464
10	20	200	23.13	-15.67	0.465
11	15	150	17.35	-15.67	0.465
12	10	96	11.10	-11.04	0.466
13	5	49	5.67	-13.35	0.466
14	-5	-52	-6.01	-20.29	0.465
15	-10	-100	-11.57	-15.67	0.465
16	-15	-150	-17.35	-15.67	0.464
17	-20	-200	-23.13	-15.67	0.466
18	-15	-150	-17.35	-15.67	0.466
19	-10	-100	-11.57	-15.67	0.4645
20	-5	-50	-5.78	-15.67	0.464
21	-5	-50	-5.78	-15.67	0.465
22	-10	-100	-11.57	-15.67	0.465
23	-15	-150	-17.35	-15.67	0.465
24	-20	-200	-23.13	-15.67	0.466
25	-15	-150	-17.35	-15.67	0.4652

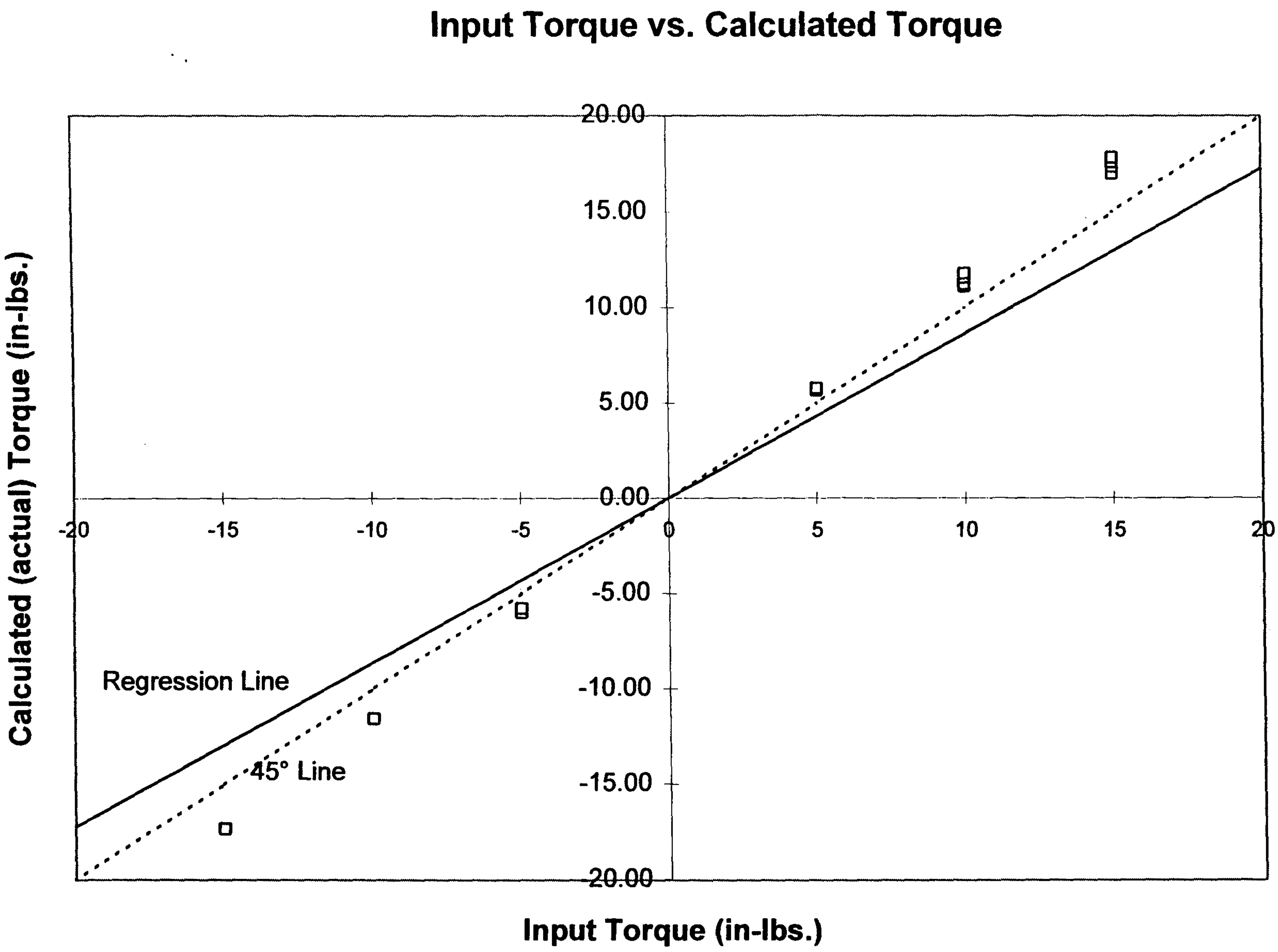
Graph Data Block Input Torque (in-lbs)	Calculated Torque (in-lbs)	Regression Line
-20	-23.13	17.25
-20	-23.13	17.25
-15	-17.35	12.94
-15	-17.35	12.94
-15	-17.35	12.94
-15	-17.35	12.94
-10	-11.57	8.62
-10	-11.57	8.62
-10	-11.57	8.62
-5	-6.01	4.31
-5	-5.78	4.31
-5	-5.78	4.31
5	5.67	4.32
5	5.78	4.32
5	5.78	4.32
10	11.10	8.63
10	11.22	8.63
10	11.57	8.63
10	11.80	8.63
15	17.00	12.95
15	17.35	12.95
15	17.58	12.95
15	17.81	12.95
20	23.13	17.26
20	23.60	17.26

average radius= 0.232494 (inches)

Regression Analysis	
a=	0.00482
b=	0.862766

R=	0.999909
R^2=	0.999818

SCATTER 1.347798


Input Torque vs. Calculated Torque
Calculated (actual) Torque (in-lbs.)
Input Torque (in-lbs.)
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-20
-15
-10
-5
0
5
10
15
20
Regression Line
45° Line

NEWTON'S LAW OF COOLING

MECH 221
Mechanical Measurements with Computer Applications

Mechanical Engineering Technology Program
Ferris State University

April 21, 1997

by
Jeremy Moehlig
and
Bob Hall
Winter Semester 1997

MECH 221 NEWTON'S LAW OF COOLING

SUMMARY

The purpose of this lab experiment was to confirm Newton's law of cooling. Newotn's law of cooling states that the time rate of change in temperature of a body is proportional to the difference in temperature between the thermal body and it's surrounding environment:

$$\frac{dT}{dt}=-k(T-T\infty)$$

T = Temp. of the body
t = time
k = reciprocal constant
T∞ = ambient temperature

In this experiment, Crisco, all vegetable shortening, is observed while it cools down towards room temperature.

MECH 221 NEWTON'S LAW OF COOLING

TABLE OF CONTENTS

MECH 221 NEWTON'S LAW OF COOLING

OBJECTIVE

The purpose of this experiment is to confirm Newton's Law of Cooling. This is to be accomplished by measurements of the change in temperature of the thermal mass.

BACKGROUND

Newton's Law of Cooling states that the time rate of change in temperature of a body is proportional to the difference in temperature between the body and it's surround environment. The equation stated in the summary corresponds to the fact that heat flows from the warmer body to the colder body, a result that is consequence of the second law of thermodynamics.

It is assumed that the temperature of the surroundings remains constant. This a reasonable assumption since the thermal mass of the surroundings is much greater then the thermal mass of the body.

Solution of the differential equation for the temperature

The differential equation for the temperature T of the body has the solution

$$\Theta = \Theta_0 \exp(-kt)$$

where Θ is the reduced temperature and Θ_0 is the initial value of the reduced temperature:

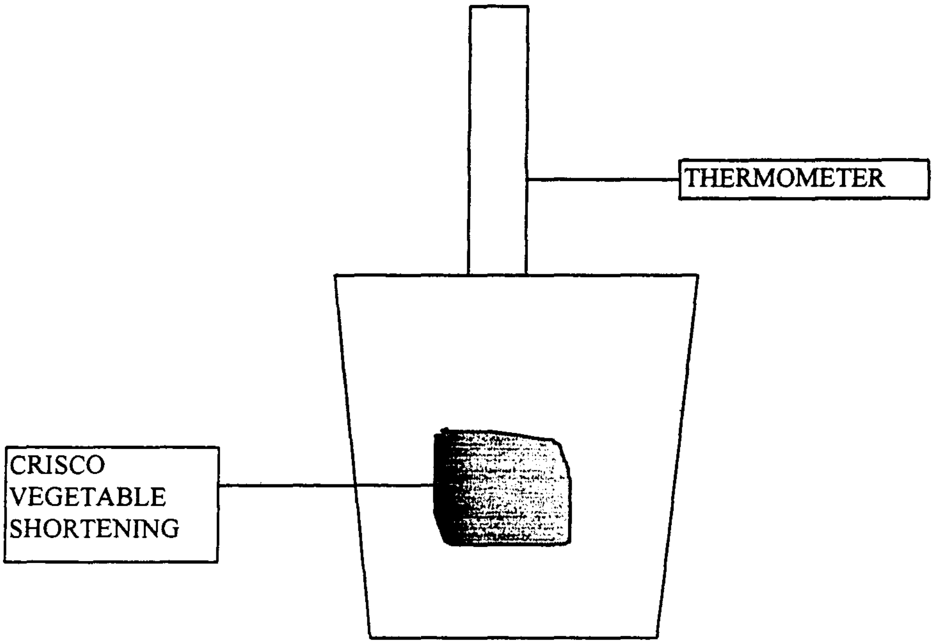
$$\Theta = \frac{T - T_\infty}{T - T_\infty}$$

$$\Theta_0 = \Theta(0)$$

Here T_1 is the initial temperature of the body at time $t = 0$.

MECH 221 NEWTON'S LAW OF COOLING

APPARATUS



EQUIPMENT

The equipment and supplies needed for this experiment include:

1. Beaker
2. Thermometer
3. Crisco all vegetable shortening
4. Stop watch

PROCEDURE

1. The beaker is filled with hot vegetable shortening and then placed in a secluded area where disturbance will be minimized.
2. The thermometer is then placed inside the cup remaining away from the sides and bottom, the thermometer is then allowed to reach the maximum temperature and measurements should begin to be taken as the temperature decent begins.
3. Measurements of the time and temperature are taken at one minute intervals for forty-one measurements.

MECH 221 NEWTON'S LAW OF COOLING

DATA REDUCTIONS AND SAMPLE CALCULATIONS

All data recorded is given on the attached spreadsheet, titled "Newton's Law of Cooling" page 9.

Theta is a proportional value of the change of temperature compared to the complete possible change in temperature. The Tamb is the surrounding temperature which in our case was 21.7 degrees Celsius.

To attain a regression line for the attached graph (page 10) the value of "a" on the attached spreadsheet corresponds to the intercept of the line.

$$a=Y-bX$$

Where X is the time and Y corresponds to Theta.

The value of "b" corresponds to the slope (the equation is as follows):

$$b = \frac{n\Sigma xy-(\Sigma x)(\Sigma y)}{n\Sigma x\text{^}2-(\Sigma x)\text{^}2}$$

The "n" refers to the number of data points.

The k value is the opposite of "b".

RESULTS AND CONCLUSIONS

Results from this experiment can be seen pictorially on the attached graph titled "Newton's Law of Cooling." The experiment data was very close to the expected values.

ERROR ANALYSIS

There are many possible human errors that could take place, ranging from not reading the thermometer or computer screen properly to miscalculating the math. Once the program is loaded on Q basic only the program and reading the computer at the right time can be the cause of error. It is also important to make sure that there isn't a breeze on the body from the surrounding environment and don't let the thermometer or thermocouple touch the side off the beaker which load the body of vegetable shortening.

Jeremy Moehlig
Bob Hall
21-Apr-97

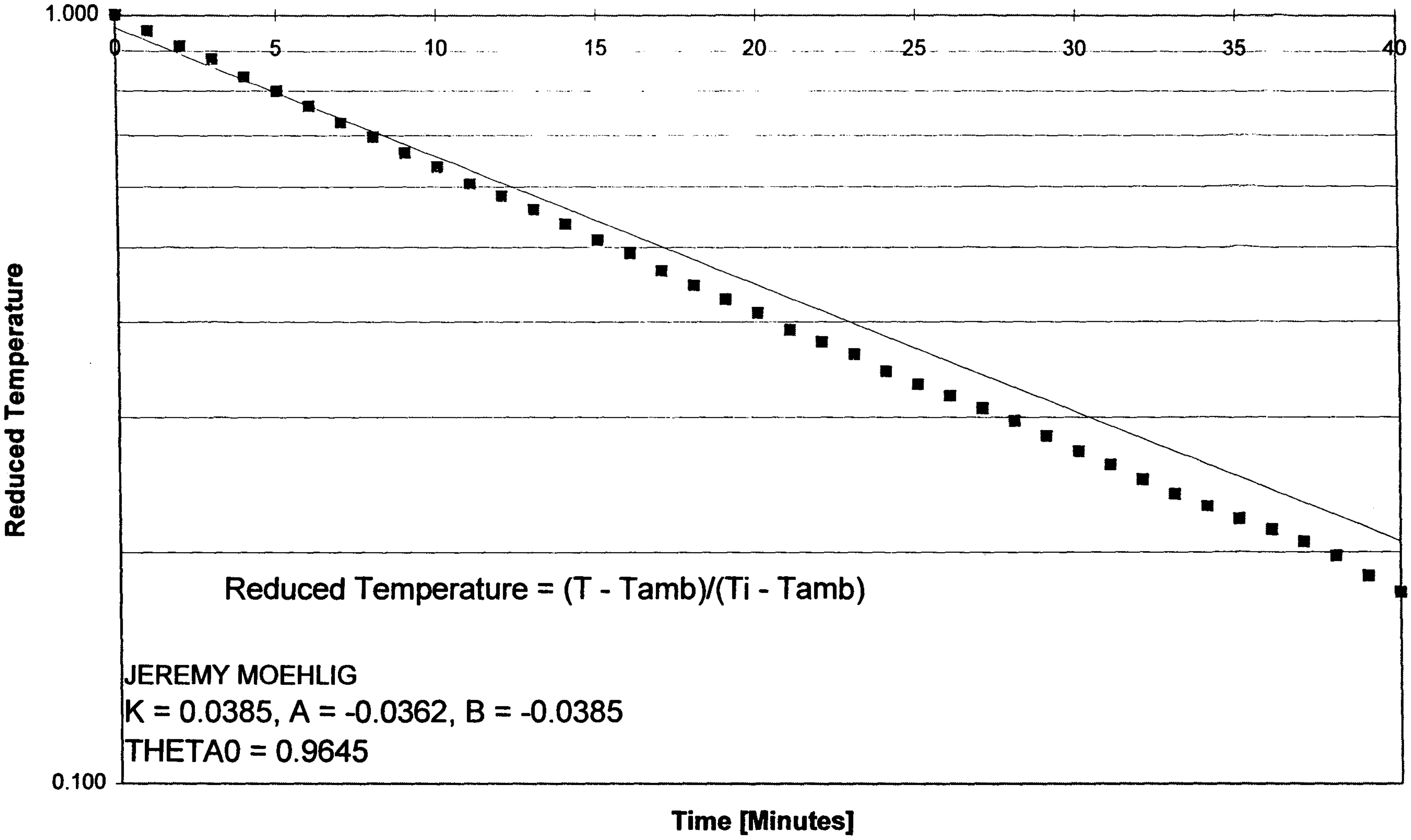
NEWTON'S LAW OF COOLING
Project #1 **WITH COMPUTER**

T_{amb}= 22.1 °C

					x	y	
					Graph		
Trial	**Time [min]**	**Temp [°C]**	**Theta**	**ln (theta)**	**Time [min]**	**Theta**	**regress**
1	0	80.3	1.000	0.000	0	1.000	0.964
2	1	77.6	0.953	-0.048	1	0.955	0.928
3	3	73.7	0.887	-0.120	2	0.913	0.893
4	4	71.0	0.839	-0.175	3	0.879	0.859
5	5	68.8	0.802	-0.221	4	0.834	0.827
6	6	66.6	0.764	-0.270	5	0.799	0.796
7	7	64.9	0.735	-0.307	6	0.764	0.766
8	8	63.3	0.707	-0.347	7	0.726	0.737
9	9	61.6	0.679	-0.388	8	0.697	0.709
10	10	60.0	0.650	-0.430	9	0.664	0.682
11	11	58.9	0.631	-0.460	10	0.636	0.656
12	12	57.6	0.610	-0.494	11	0.606	0.632
13	13	55.6	0.575	-0.554	12	0.583	0.608
14	14	54.5	0.556	-0.587	13	0.560	0.585
15	15	52.8	0.527	-0.640	14	0.536	0.563
16	16	52.3	0.518	-0.658	15	0.512	0.542
17	17	50.6	0.490	-0.714	16	0.490	0.521
18	18	49.5	0.471	-0.753	17	0.466	0.501
19	19	48.4	0.452	-0.794	18	0.446	0.483
20	20	47.9	0.442	-0.815	19	0.428	0.464
21	21	46.8	0.424	-0.859	20	0.411	0.447
22	22	45.7	0.405	-0.905	21	0.391	0.430
23	23	45.1	0.395	-0.928	22	0.376	0.414
24	24	44.0	0.376	-0.977	23	0.363	0.398
25	25	43.5	0.367	-1.003	24	0.345	0.383
26	26	42.4	0.348	-1.056	25	0.331	0.369
27	27	41.8	0.338	-1.083	26	0.320	0.355
28	28	41.3	0.329	-1.112	27	0.308	0.341
29	29	40.7	0.320	-1.141	28	0.297	0.328
30	30	40.2	0.310	-1.171	29	0.283	0.316
31	31	39.6	0.301	-1.202	30	0.271	0.304
32	32	39.1	0.291	-1.234	31	0.260	0.293
33	33	38.0	0.272	-1.301	32	0.249	0.282
34	34	37.4	0.263	-1.336	33	0.238	0.271
35	35	36.9	0.254	-1.369	34	0.229	0.261
36	36	36.3	0.244	-1.411	35	0.221	0.251
37	37	35.8	0.235	-1.446	36	0.214	0.241
38	38	35.2	0.225	-1.491	37	0.206	0.232
39	39	34.7	0.216	-1.530	38	0.198	0.224
40	40	34.1	0.206	-1.579	39	0.186	0.215
41	41	33.6	0.197	-1.626	40	0.178	0.207

a= -0.0362
b= -0.0385
Theta$_o$= 0.9645
k= 0.0385
r= -0.99934
r^2= 0.99868
sqrt(1-r^2)= 0.036
%= 3.6%
Theta= (T-Tamb)/(T1-Tamb)
ln Theta= ln Theta0-kt
b= slope= slope(lnTheta,Time)
a= intercept= intercept(ln Theta, Time)
k= -b
r= correlation correl(ln Theta, time)
Regression line= Theta*exp(kt)
Theta$_o$= exp(a)
Tamb= initial temperature

NEWTON'S LAW OF COOLING



Reduced Temperature = (T - Tamb)/(Ti - Tamb)

JEREMY MOEHLIG
K = 0.0385, A = -0.0362, B = -0.0385
THETA0 = 0.9645

Jeremy Moehlig
Bob Hall
21-Apr-97

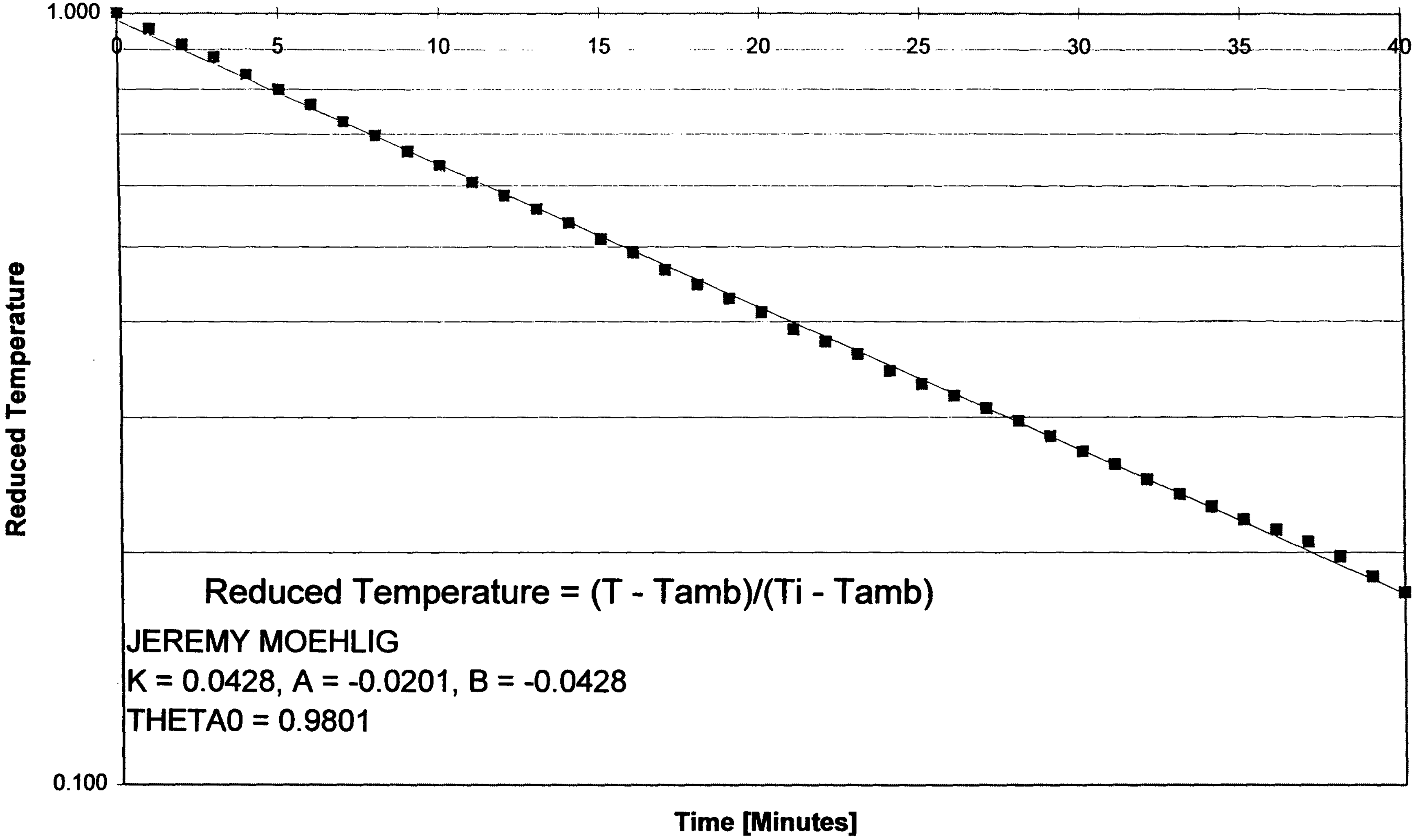
NEWTON'S LAW OF COOLING
Project #1 **WITH THERMOMETER**

T_{amb}= 21.6 °C

Trial	Time [min]	Temp [°C]	Theta	ln (theta)	x Graph Time [min]	y Theta	regress
1	0	125.8	1.000	0.000	0	1.000	0.980
2	1	121.1	0.955	-0.046	1	0.955	0.939
3	2	116.7	0.913	-0.091	2	0.913	0.900
4	3	113.2	0.879	-0.129	3	0.879	0.862
5	4	108.5	0.834	-0.182	4	0.834	0.826
6	5	104.9	0.799	-0.224	5	0.799	0.791
7	6	101.2	0.764	-0.269	6	0.764	0.758
8	7	97.3	0.726	-0.320	7	0.726	0.726
9	8	94.2	0.697	-0.361	8	0.697	0.696
10	9	90.8	0.664	-0.409	9	0.664	0.667
11	10	87.9	0.636	-0.452	10	0.636	0.639
12	11	84.7	0.606	-0.502	11	0.606	0.612
13	12	82.3	0.583	-0.540	12	0.583	0.586
14	13	79.9	0.560	-0.581	13	0.560	0.562
15	14	77.5	0.536	-0.623	14	0.536	0.538
16	15	74.9	0.512	-0.670	15	0.512	0.516
17	16	72.7	0.490	-0.713	16	0.490	0.494
18	17	70.2	0.466	-0.763	17	0.466	0.473
19	18	68.1	0.446	-0.807	18	0.446	0.453
20	19	66.2	0.428	-0.849	19	0.428	0.434
21	20	64.4	0.411	-0.890	20	0.411	0.416
22	21	62.3	0.391	-0.940	21	0.391	0.399
23	22	60.8	0.376	-0.978	22	0.376	0.382
24	23	59.4	0.363	-1.014	23	0.363	0.366
25	24	57.5	0.345	-1.066	24	0.345	0.351
26	25	56.1	0.331	-1.105	25	0.331	0.336
27	26	54.9	0.320	-1.141	26	0.320	0.322
28	27	53.7	0.308	-1.177	27	0.308	0.308
29	28	52.5	0.297	-1.216	28	0.297	0.296
30	29	51.1	0.283	-1.262	29	0.283	0.283
31	30	49.8	0.271	-1.307	30	0.271	0.271
32	31	48.7	0.260	-1.347	31	0.260	0.260
33	32	47.5	0.249	-1.392	32	0.249	0.249
34	33	46.4	0.238	-1.435	33	0.238	0.239
35	34	45.5	0.229	-1.472	34	0.229	0.229
36	35	44.6	0.221	-1.511	35	0.221	0.219
37	36	43.9	0.214	-1.542	36	0.214	0.210
38	37	43.1	0.206	-1.578	37	0.206	0.201
39	38	42.2	0.198	-1.621	38	0.198	0.193
40	39	41.0	0.186	-1.681	39	0.186	0.185
41	40	40.1	0.178	-1.729	40	0.178	0.177

a= -0.0201
b= -0.0428
$Theta_o$= 0.9801
k= 0.0428
r= -0.99971
r^2= 0.99943
sqrt(1-r^2)= 0.024
%= 2.4%
Theta= (T-Tamb)/(T1-Tamb)
ln Theta= ln Theta0-kt
b= slope= slope(lnTheta,Time)
a= intercept= intercept(ln Theta, Time)
k= -b
r= correlation correl(ln Theta, time)
Regression line= Theta*exp(kt)
$Theta_o$= exp(a)
Tamb= initial temperature

NEWTON'S LAW OF COOLING



Reduced Temperature = (T - Tamb)/(Ti - Tamb)

JEREMY MOEHLIG
K = 0.0428, A = -0.0201, B = -0.0428
THETA0 = 0.9801

Drag Coefficient for a 60 Degree Triangle and a Rectangle

by

Robert E. Hall
Lab Partner: Jeremy Moehlig

Mech 221
Mechanical Measurements with Computer Applications

April 29, 1997

SUMMARY

The drag coefficient of a given object is a dimensionless factor. It depends upon the geometric shape of the object and its orientation in the air flow or fluid flow, but for this lab, a wind tunnel was used so air flow was present. The drag force of a given object is found by the equation:

$$C_d = \frac{F_d}{1/2 \rho V^2 A}$$

Fd is the drag force which can be measured using a strain gage and a quarter bridge setup. P is the air density which for the purposes of this lab was estimated to be .002309 slugs/ft^3. V is the velocity which has the units of fpm and should be converted to fps. The velocity was obtained by placing a pitot tube inside the wind tunnel to measure the velocity in inches of water. It is important to place the tube just above the center of the tunnel so that it doesn't interrupt the air flow toward the specimen. A is the frontal area of the object that is attacked by the air flow.

CONTENTS

I. OBJECTIVE

The objective of this experiment was to recreate the drag coefficients for a 60 degree triangle and a rectangle.

II. APPARATUS

1. A low velocity wind tunnel
2. A pitot static tube
3. Test specimens out of Wood
4. Strain gage
5. Strain gage indicator
6. Second strain gage(used as dummy in quarter bridge circuit)
7. Strain gage bridge with attached rod(mounted on wind tunnel)
8. MicroMeasurements strain gage application kit
9. Fish scale
10. standard weights
11. Calipers
12. standard ruler
13. Marker
14. Tensile bar

III. PROCEDURE

1. Calibrate the fish scale using a standard weight of about 5 lbs. Record data.
2. Using the ruler, measure the spot on the rod where the center of the test specimen is to be placed. Mark the spot with the marker.
3. Lay a strain gage on the strain gage bridge using the MicroMeasurements strain gage application kit.
4. Connect the strain gage up in a quarter bridge circuit to the strain gage indicator.
note: a dummy strain gage must be used which may be attached to a simple tensile bar.
5. Calibrate the strain gage by pulling on the marked spot on the rod with the fish scale at 5 lbs. Record Data.
6. Place the test specimen in the wind tunnel in the desired orientation.
7. Insert the pitot static tube in the path of the airflow but try no to obstruct the air flow traveling towards the specimen.
8. Turn on the air tunnel and take several readings (about 5 or so) at different throttle positions. Be sure to record the strain indicator and the pitot tube for each throttle position.
9. After 5 throttle positions are taken, then try the same throttle positions a second time to see if the readings can be recreated.

IV. EXPERIMENTAL OBSERVATIONS

During the experiment the test specimen was spinning around on the rod, so it is necessary to make sure that the specimen is properly secured to the rod. The readings that were taken were in fact easily recreated. The pitot static tube gave an accurate readout and the strain gage indicator gave a readout as long as the proper calibration procedure was followed. The units on the measurands need to be noted because various unit conversions should be used such as converting fpm to fps for example. It also may be of some use to calculate the Reynold's number in order to check the air flow within the wind tunnel.

V. CALCULATIONS

The calculations are shown on the attached MicroSoft Excel Spreadsheets.

VI. ERROR ANALYSIS

There were several methods of error in the experiment performed, but these methods didn't push the outcome too far away from the actual, so the data does retain some significance. One possible error is in the calibration of the fish scale and the strain gage indicator. The desired outcome is to have the strain gage indicator reading directly in lbs of force, but with human error present in the calibration between the fish scale and the strain gage indicator, the indicator may not be as accurate as it could be. Another possible error would be in the fish scale positioning on the rod inside the tunnel. This is also a factor of the calibration as calibrating the instruments is a very vital part of this experiment. It was determined that if the fish scale wasn't placed right on the mark, then there could be anywhere from a 10% to a 20% error in the calibration. This is because if the scale is within 2 inches of the mark and the rod is 12 inches long, then that equates to a 20% error. Since the trained eye wouldn't be anywhere close to two inches off the mark, this error seemed to be a minor error in the experiment. A third possible error could be the placement of the pitot tube because if the pitot tube is in the path of the air flow, it could be created an obstruction to the test specimen. Overall, the recorded data for the triangle came within a max of %30 error and a minimum %15 error. For the rectangle a max %10 error and a min %2 error.

VII. RESULTS AND CONCLUSIONS

The results are shown on the attached spreadsheets and graphs. The results show that the drag coefficients may be reproduced for specific shapes.

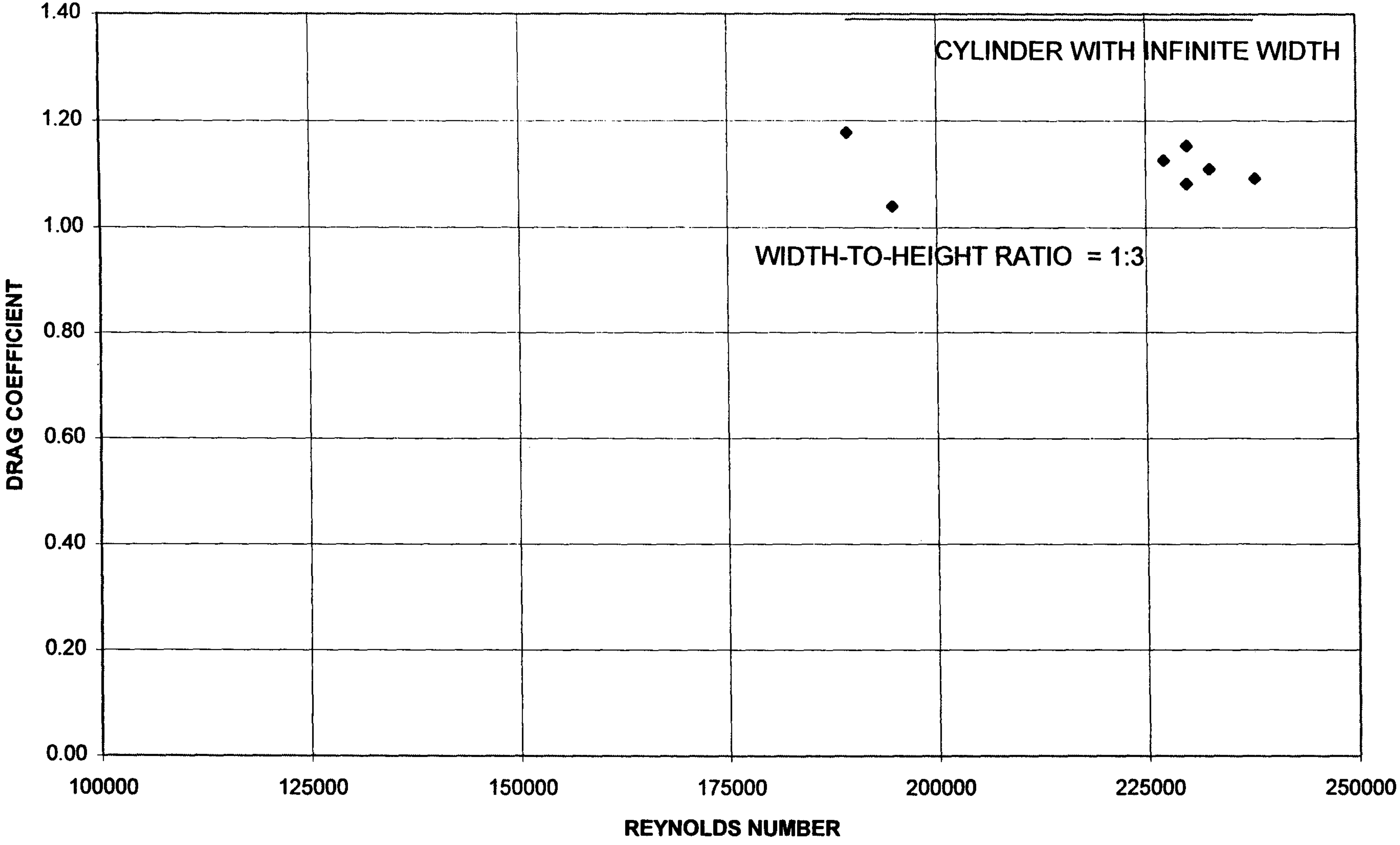
VIII. REFERENCES

1. Mechanical Measurements text chapter 3.
2. Microsoft Excel Reference Manual
3. Fluid Mechanics by Robert Mott chapter 17
4. MicroMeasurements strain gage installation manual.

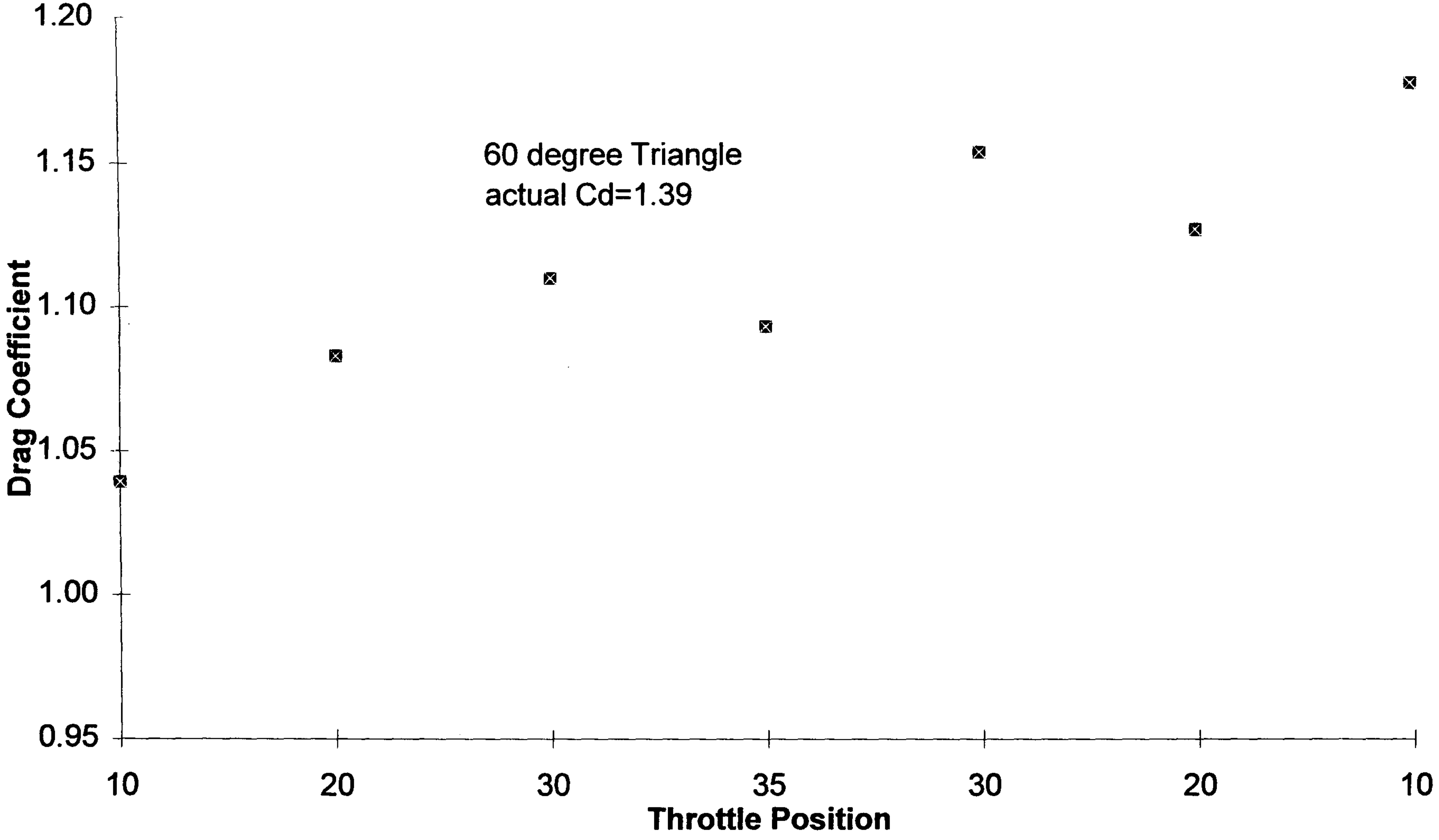
WIND TUNNEL EXPIRAMENT---DRAG COEFFICIENT							
Robert Hall Jeremy Moehlig							0.333333
temp 20.3-20.4							
			AREA MEASUREMENTS				
	Rectangle				Trianlge		
	base	height	area		base	height	area
1	3.27	1.3495	4.412865	1	1.284	3.75	4.815
2	3.282	1.349	4.427418	2	1.28	3.7	4.736
3	3.272	1.3482	4.41131	3	1.282	3.8	4.8716
4	3.268	1.3495	4.410166	4	1.285	3.82	4.9087
5	3.27	1.348	4.40796	5	1.279	3.72	4.75788
6	3.275	1.355	4.437625	6	1.282	3.65	4.6793
7	3.272	1.3482	4.41131	7	1.276	3.75	4.785
8	3.28	1.3492	4.425376	8	1.284	3.72	4.77648
9	3.273	1.3495	4.416914	9	1.28	3.75	4.8
10	3.275	1.352	4.4278	10	1.278	3.8	4.8564
11	3.27	1.3495	4.412865	11	1.275	3.75	4.78125
12	3.28	1.349	4.42472	12	1.285	3.72	4.7802
		ave	4.418328			3.744167	4.795651
sdeviation	0.004582	0.001958	0.009372	sdeviation	0.003407	0.047378	0.061851
n	12	12	12	n	12	12	12
c	0.95	0.95	0.95	c	0.95	0.95	0.95
a	0.05	0.05	0.05	a	0.05	0.05	0.05
nu	11	11	11	nu	11	11	11
t	2.200986	2.200986	2.200986	t	2.200986	2.200986	2.200986
delta d	0.002911	0.001244	0.005955	delta d	0.002165	0.030103	0.039299
ave	3.273917	1.349717	4.418861	ave	1.280833	3.744167	4.795651
hi	3.276828	1.350961	4.424815	hi	1.282998	3.774269	4.834949
low	3.271006	1.348473	4.412906	low	1.278669	3.714064	4.756352

TEMP-22.0(72F)											
RELATIVE HUMIDITY = 50%					Length [ft]	AREA		AREA		Dynamic	
BAROMETRIC PRESS= 29.8 (ESTIMATE)				**Rectangle**	0.1041667	4.4183281	in.^2	0.030683	ft^2	Viscosity	
CORRECTION FACTOR=.995				**Triangle**	0.265625	4.7956508	in.^2	0.033303	ft^2	1.81E-05	Pa.s
RHO	0.0743	lbs/ft^3	0.002309	slugs/ft^3						3.78E-07	lb.s/ft^2
CALIBRATION---5LBS=500 INDICATED						Calibrated	Calibrated				
			Corrected		Corrected	strain gage	fish scale	Drag	Reference	Reynolds	percent
	Throttle	Manometer	Velocity	nom V	Velocity	Drag	correction	Coefficient	(Mott)	Number	error
	position	inches water	fpm	fpm	fps	lbs	5.5lbs=3.5lbs		60 Triangle		
triangle	10	3.2	7200	7100	120	0.42	0.58	1.04	1.39	1.95E+05	0.25
	20	4.4	8500	8500	142	0.61	0.84	1.08		2.30E+05	0.22
	30	4.8	8600	8700	143	0.64	0.88	1.11		2.33E+05	0.20
	35	4.9	8800	8800	147	0.66	0.90	1.09		2.38E+05	0.21
	30	4.7	8500	8600	142	0.65	0.89	1.15		2.30E+05	0.17
	20	4.5	8400	8400	140	0.62	0.85	1.13		2.27E+05	0.19
	10	3.2	7000	7100	117	0.45	0.62	1.18		1.89E+05	0.15
rectangle	10	3.1	7000	7100	117	0.42	0.58	1.19	rectangle	7.42E+04	0.02
	20	4.3	8400	8400	140	0.64	0.88	1.26	a/b=2.6	8.91E+04	0.08
	30	4.6	8600	8600	143	0.64	0.88	1.20	between	9.12E+04	0.03
	35	4.6	8600	8600	143	0.64	0.88	1.20	1.16-1.17	9.12E+04	0.03
	30	4.5	8400	8500	140	0.62	0.85	1.22		8.91E+04	0.05
	20	4.3	8400	8400	140	0.63	0.86	1.24		8.91E+04	0.07
	10	3.0	7000	7000	117	0.37	0.51	1.05		7.42E+04	0.10
	Cd	Cd									
	triangle	rectangle									
sdeviation	0.137	0.161									
n	7	7									
c	0.95	0.95									
a	0.05	0.05									
nu	6	6									
t	2.447	2.447									
delta d	0.127	0.149									
ave	0.79	0.78									
hi	0.919	0.924									
low	0.666	0.626									

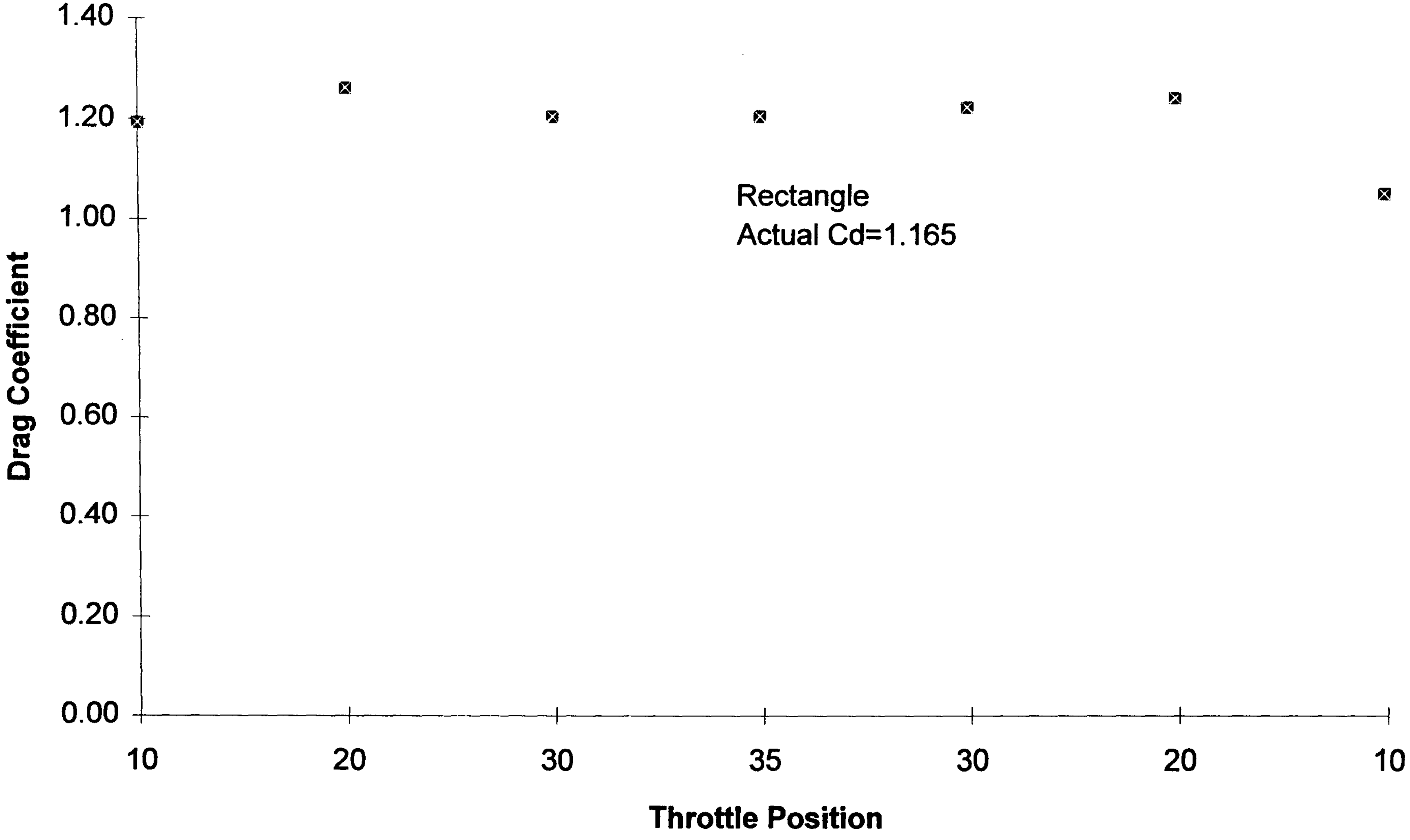
DRAG COEFFICIENT OF A 60 DEGREE WEDGE

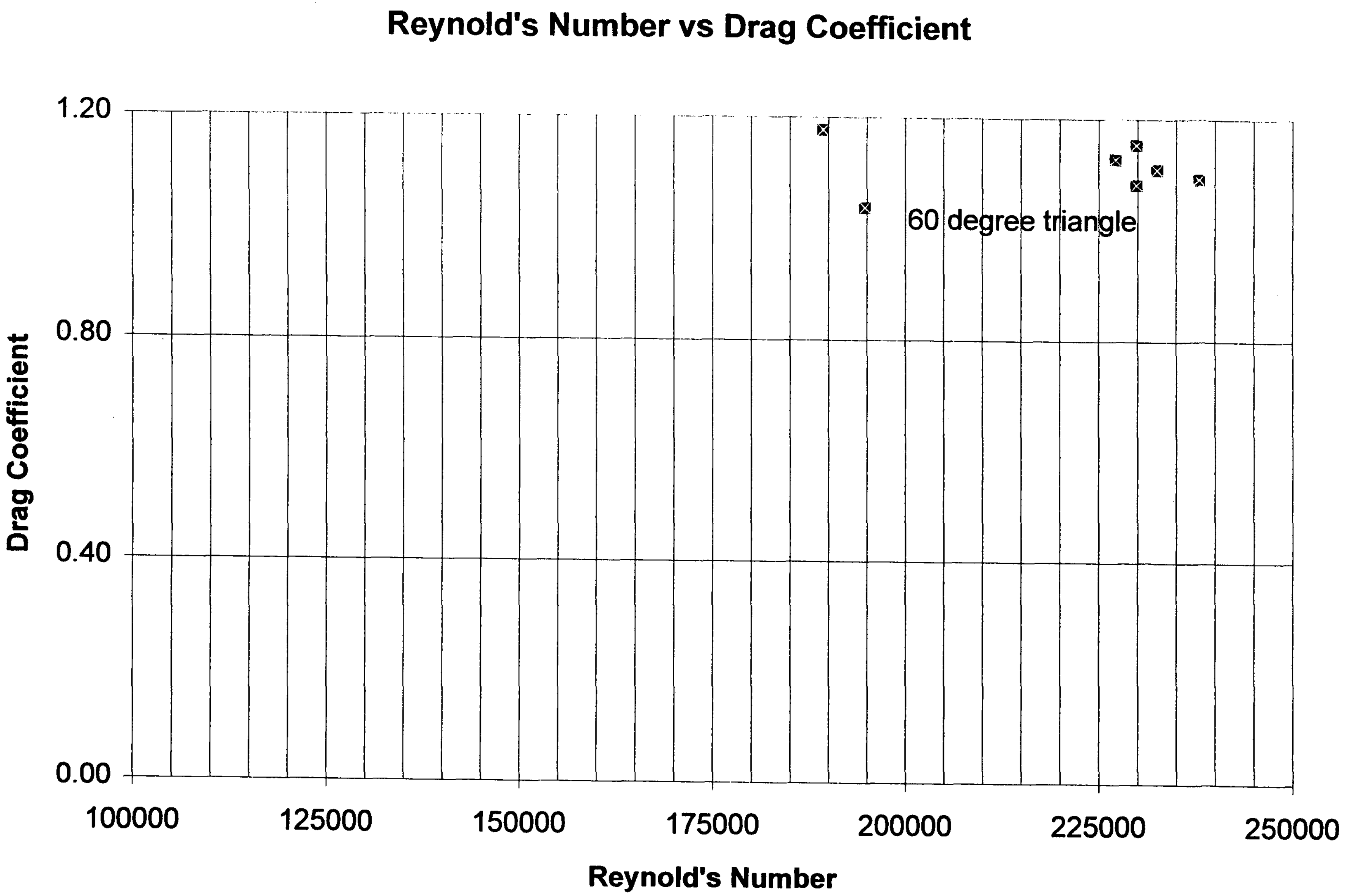


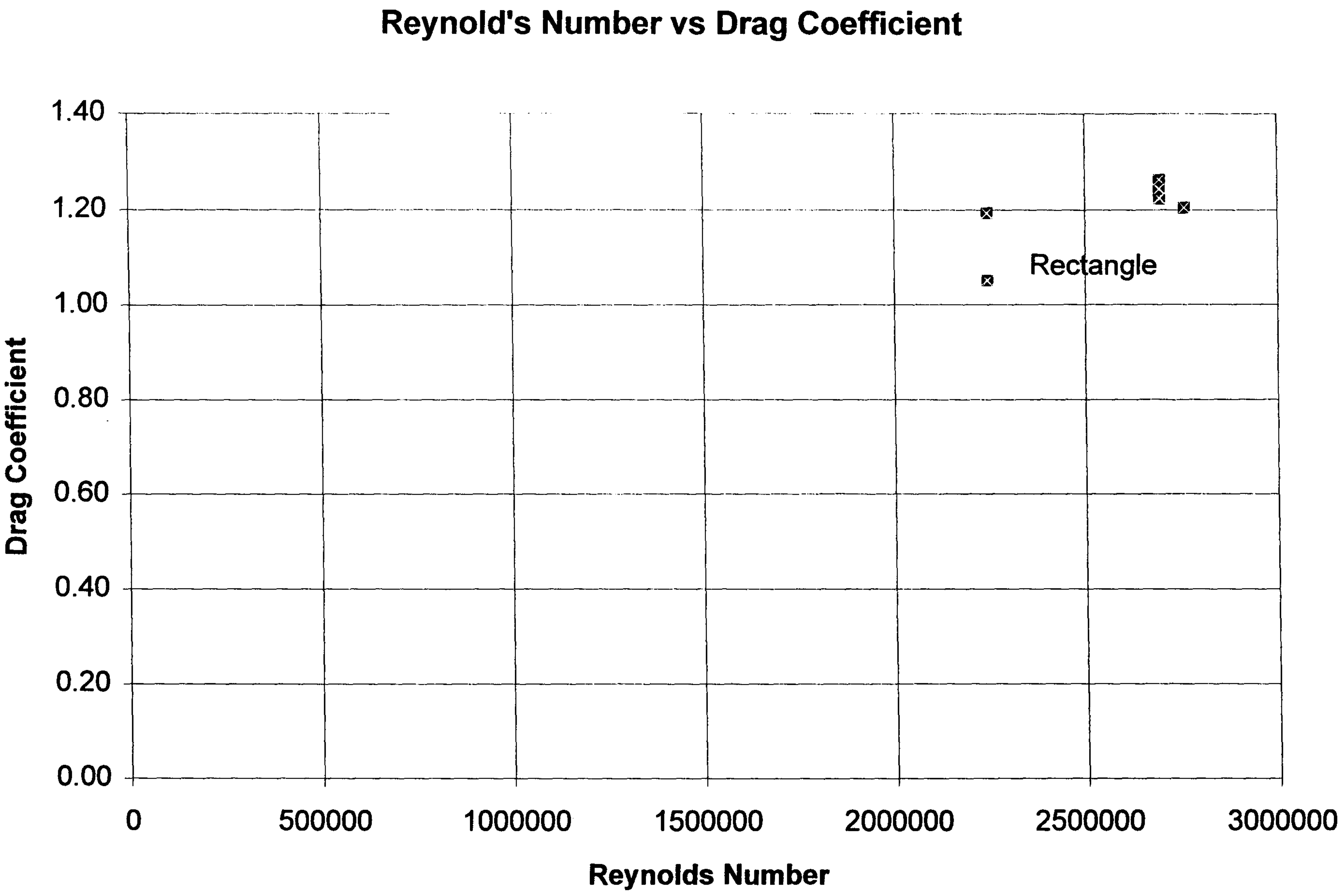
Throttle Position vs Drag Coefficient



Throttle Position vs Drag Coefficient




Reynold's Number vs Drag Coefficient
1.20
0.80
0.40
0.00
Drag Coefficient
100000
125000
150000
175000
200000
225000
250000
Reynold's Number
60 degree triangle


Reynold's Number vs Drag Coefficient
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Drag Coefficient
Rectangle
0
500000
1000000
1500000
2000000
2500000
3000000
Reynolds Number

THIS PAGE IS FOR GRAPH CREATION PURPOSES ONLY								
	throttle position	Cd	Reynold's number	Infinite Cyl Drag		throttle position	Cd	Reynold's number
triangle	10	1.04	194678	1.39	rectangle	10	1.19	2244523
	20	1.08	229828	1.39		20	1.26	2693428
	30	1.11	232532	1.39		30	1.20	2757557
	35	1.09	237940	1.39		35	1.20	2757557
	30	1.15	229828	1.39		30	1.22	2693428
	20	1.13	227124	1.39		20	1.24	2693428
	10	1.18	189270	1.39		10	1.05	2244523
	194678	1.04				2244523	1.19	
	229828	1.08				2693428	1.26	
	232532	1.11				2757557	1.20	
	237940	1.09				2757557	1.20	
	229828	1.15				2693428	1.22	
	227124	1.13				2693428	1.24	
	189270	1.18				2244523	1.05	

REAL TIME PRESSURE AND TEMPERATURE TRANSDUCING

CALIBRATION OF A STARBUCK 8232 A-D CONVERTER

MECH 221
Mechanical Measurements With Computer Data Applications

Mechanical Engineering Technology Program
Ferris State University

April 28, 1997

by
Alan Cook
Jason Roelle

MECH 221 CALIBRATION OF A STARBUCK 8232 A-D CONVERTER

I. OBJECTIVE

The objective of this experiment is to observe the Counts -vs- the calibrated thermometer and pressure gage, with response of the Starbuck 8232 anaolog-to-digital converter and to prepare the calibration curve. There was also a computer program which we developed to control the Starbuck 8232 converter in it's "Immediate Communications" mode.

II. APPARATUS

The apparatus below consist of the following component parts.

1. Starbuck 8232 A-D Converter with 8-bit RS-232 communications port protocol.
2. 486 DX2 50 Mhz Computer.
3. RS- 232 25-pin cable.
4. Digital Voltmeter.
5. 0-5 Volt Power Supply with Potentiometer.

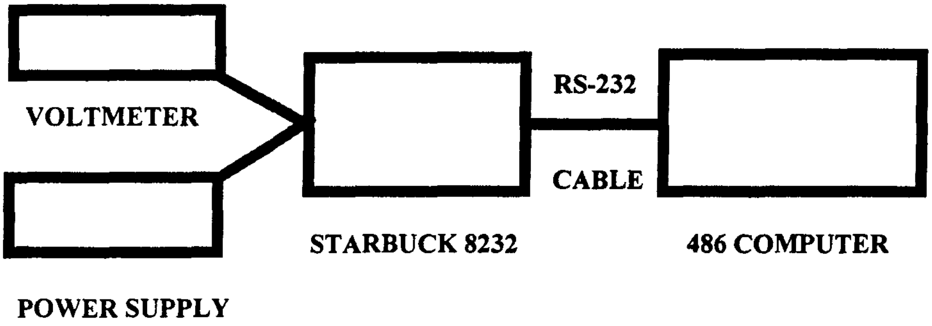


Figure. Apparatus Arrangement for Starbuck 8232 Calibration

III. PROCEDURE

The calibration was accomplished using the following steps:

1. Write a QBASIC program for communication with the Starbuck 8232 converter.
2. Calibrate the thermometer using the ice point and boiling point.
3. Calibrate the pressure gage using the Dead Weight Pressure Tester.
4. Install the apparatus.
5. Turn on the power.

6. Run the QBASIC program.
7. Vary the counts form the analog input from 0 to 255 counts.
8. Record the counts while at the same time record the given pressure and temperature from the calibrated thermometer and pressure gage.
9. Calibrate the Starbuck using the offset bias and the slope in the QBASIC program by giving a,b,c, and d values.

IV. EXPERIMENTAL OBSERVATIONS

The analog output was varied from 105 to 211 counts when the pressure was varied from 20 to 60 psi. The temperature range was varied from 0 to 77 Degree's Celsius when the counts where varied from 107 to 255. The slope of the temperature was found to be (1.92207), and the slope for the pressure was found to be (2.65). During the data taking the following observations were made.

1. No drift with the time of the out put was noted. (The counts Held Steady)
2. No hystereresis effects were seen.
3. No outliars were identified.

V CALCULATIONS

The counts-Vs- calibrated material were reduce using a Microsoft Excel spread sheet which is attached.

Slope= (Rise / Run)
Kpa to psi= (1 psi = 6.88935 KPa)

VI. ERROR ANALYSIS

The published calibration value for the Starbuck 8232 relates to a full scale output of 255 counts base 10 (or 1111111 base 2). This corresponds to a DC analog input of 5.0 volts. The digital output may be expected to have an error of +- 1 bit (1/255). This equals approximately +- .02 volts (+-20mV) or +-.39% of full scale. The statistics from the calibration data confirm this error assessment. The output of the Starbuck 8232 A-D converter is indeed found to be a linear function of the input.

VII. RESULTS AND CONCLUSIONS

The calibration of the Starbuck 8232 analog-digital converter are presented in the attached spreadsheets and graphs. The results are as follows.

1. The Starbuck 8232 unit does provide a constant linear digital response to an analog input
2. The calculated values of the slope were found to be (1.92207) for the temperature calibration, and (2.65) for the pressure calibration using the pressure transducer.
3. No drift counts output or hysteresis affect was observed.
4. The data appears to be consistent with no out liars.

Two factors appear to limit the calibration of the Starbuck 8232 converter. The first is that you can only calibrate it as accurately as the calibrated thermometer and pressure gage. Second for the Temperature you can only calibrate to the ice point because the boil point is out of the range of 250 counts.

VII. REFERENCES

1. Starbuck 8232 Operations Manual.
2. Microsoft QBASIC Manual.
3. G. R. Olsson, Professor of Mechanical Engineering at Ferris State University.

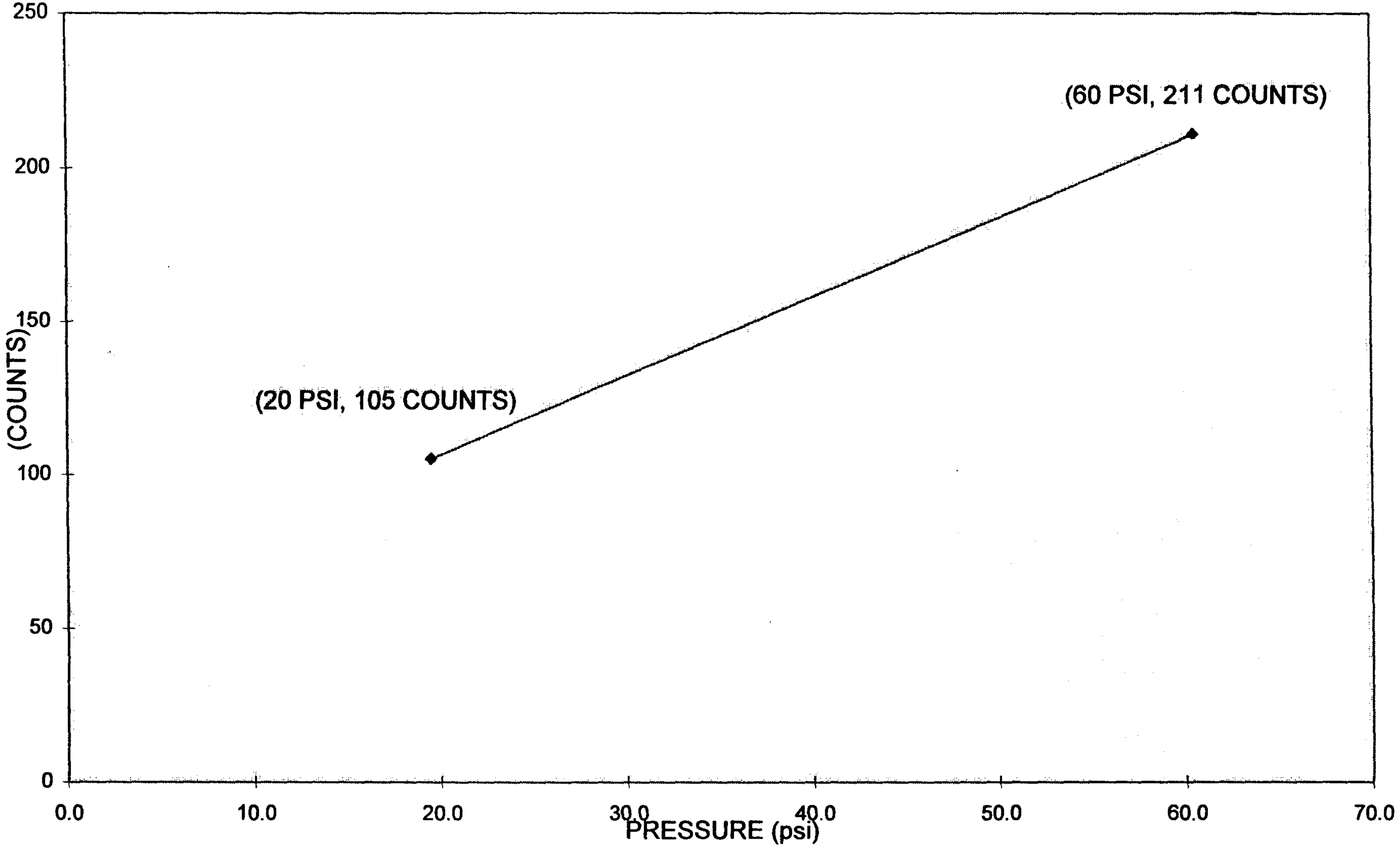
VIII. SUMMARY

A Starbuck 8232 8 bit analog digital converter was calibrated using QBASIC, pressure gage, and a thermometer. The pressure and temperature were calibrated by finding the slopes (thermometer and pressure gage-vs-counts). The slope is used in the QBASIC program to calibrate the Starbucks read out which is given in (psi or degrees Celsius). The Starbuck is a useful tool for giving digital read outs since it can be used in many applications, and is easily calibrated.

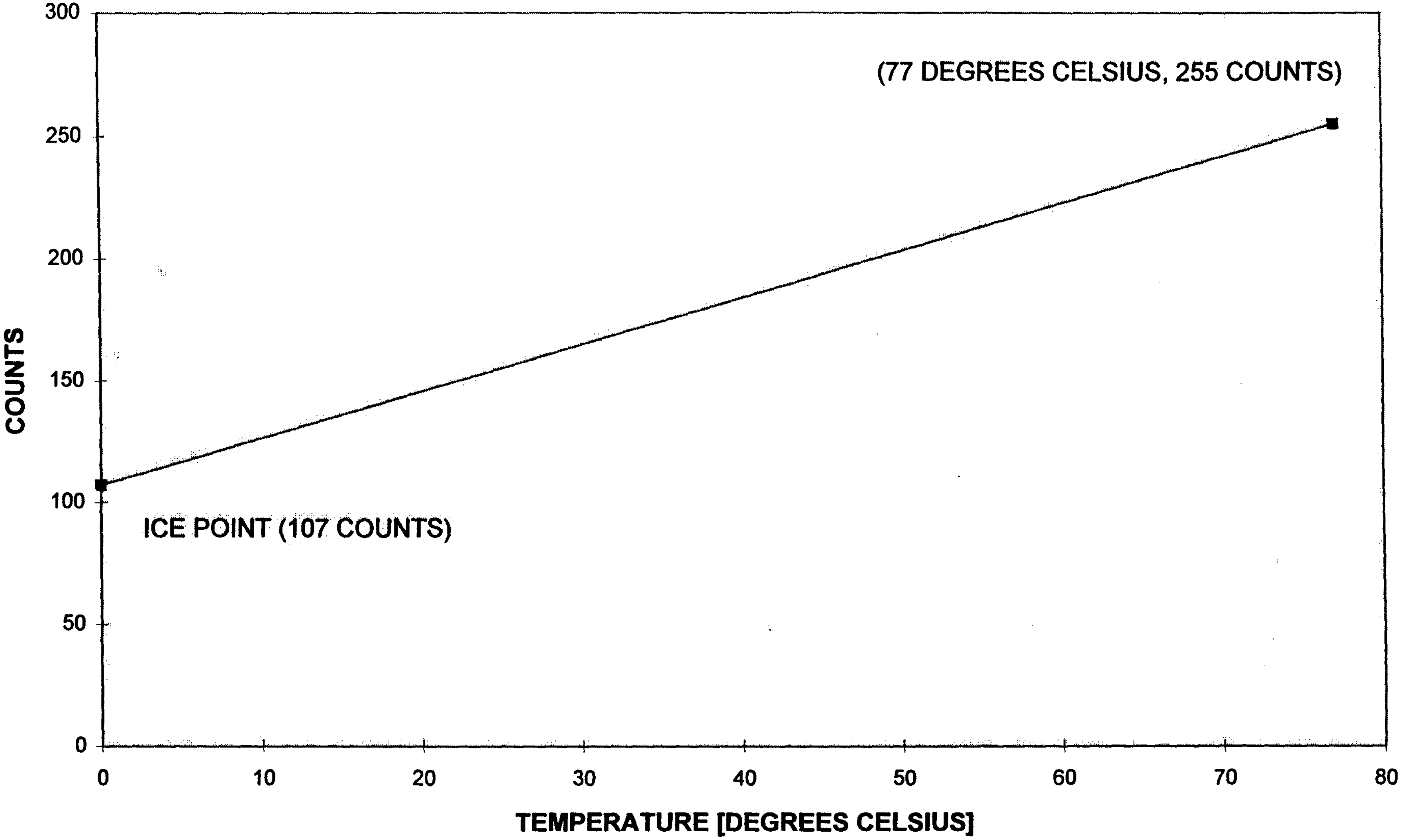
TABLE# 1 CALIBRATION OF THE PRESSURE TRANCDUCER								
						Alan Cook and Jason Roelle		
		Nominal	Corrected		Corrected	Counts		
Trial	Counts	Out Put			Pressure			
#		(psi)	[psi]		psi			
1	105	20	19.50265		19.5	105		
2	211	60	60.52127		60.5	211		
TABLE# 2 CALIBRATION OF THE THERMO COUPLE								
Trial	Counts	Out Put						
#		Celsius						
1	107	0	ICE POINT		0	107		
2	255	77	MAX COUNTS		77	255		
TABLE# 3 CALIBRATION OF THE THERMOMETER								
Trial	Out Put	Determined						
#	(Co)	(Co)						
1	0.5	0	ICE POINT		0	0.5		
2	100	100	BOIL POINT		100	100		
TABLE# 4 CALIBRATION OF THE DEAD WEIGHT PRESSURE TESTER								
		Applied	Indicated	Regression				
Trial	Mass	Pressure	Pressure					
#	(Kg)	[kPa]	(KPa)	[kPa]	p(ind) = a + b*p(applied)			psi
1	1	31	33	37	Intercept	6.7667	a	0.981668
2	1	31	35	37	Slope	0.9752	b	
3	1	31	35	37	R	0.9996		
4	1	31	36	37	R^2	0.9992		
5	1	31	36	37	(1-R2)^.2	2.8	%	
6	1	31	36	37				
7	2	62	66	67	p(corrected) = (p(indicated) - a)/b			
8	2	62	68	67				
9	2	62	69	67				
10	2	62	69	67				
11	2	62	69	67				
12	2	62	69	67				
13	3	93	98	97				
14	3	93	99	97				
15	3	93	99	97				
16	3	93	99	97				
17	3	93	99	97				
18	3	93	99	97				
19	4	124	125	127				
20	4	124	126	127				
21	4	124	127	127				
22	4	124	127	127				
23	4	124	127	127				

24	4	124	127	127				
25	5	155	157	157				
26	5	155	157	157				
27	5	155	158	157				
28	5	155	158	157				
29	5	155	158	157				
30	5	155	158	157				
31	6	185	186	188				
32	6	185	187	188				
33	6	185	187	188				
34	6	185	187	188				
35	6	185	187	188				
36	6	185	188	188				

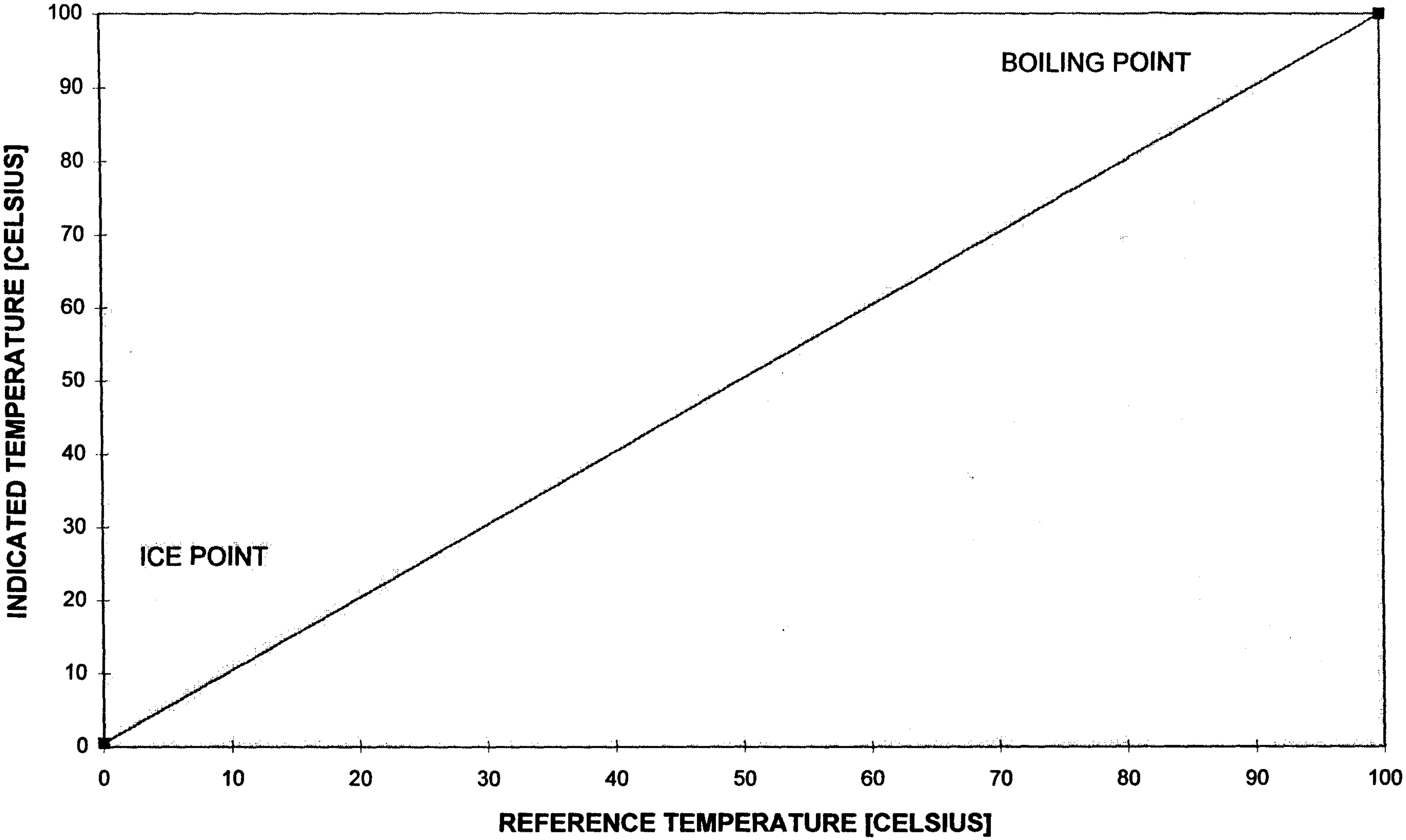
CALIBRATION OF A PRESSURE TRANSDUCER



CALIBRATION OF A THERMOCOUPLE



THERMOMETER CALIBRATION

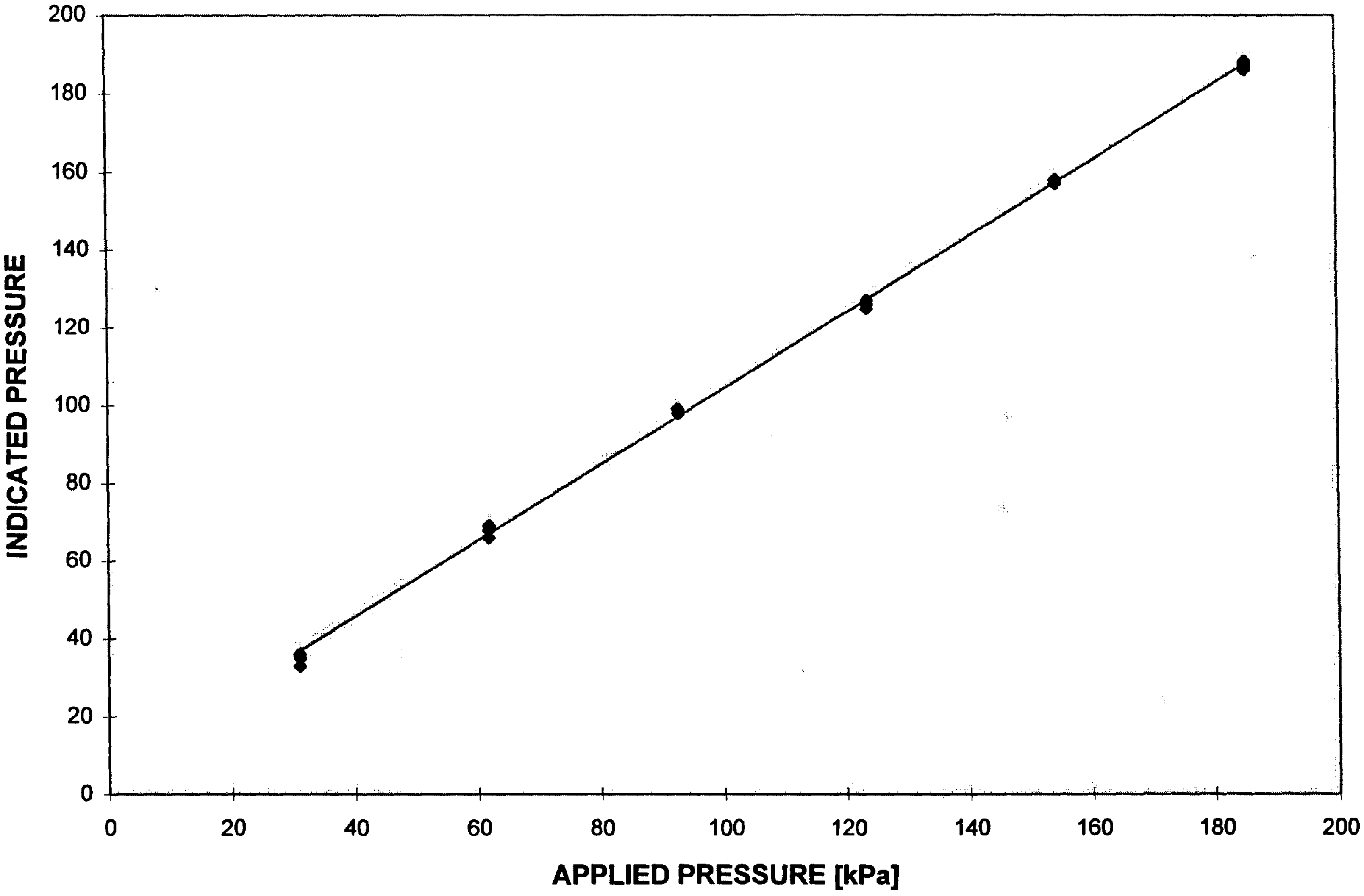


Mechanical Engineering Technology

Student Projects
1997-1998

Section 3 of 3

PRESSURE GAGE CALIBRATION



```
'QBASIC PROGRAM FOR STARBUCK 8232 IMMEDIATE COMMUNICATION MODE
'                By Jason Roelle, 3-24-97, Version 3.21
' ==================================================================
'       SUBROUTINE DECLARATIONS
' ---------------------------------------------------
  DECLARE SUB SetScreen ()
  DECLARE SUB Handshake ()
  DECLARE SUB PauseTime ()
  DECLARE SUB AnalogInput ()
' ===================================================================
'       INTIALIZATION
' ------------------------------------------------------
  DEFINT A-Z
  OPEN "COM2:1200,E,7,1,RS,CS,DS,CD" FOR RANDOM AS #1
  escapeCode$ = CHR$(9)
  a! = -107 * 77 / 148
  b! = 77 / 148
  c! = 20 - 40 * 105 / 106
  d! = 40 / 106
  recogCode$ = "01"
  CALL SetScreen
  CALL Handshake
' ======================================================================
'       MAIN CALLING PROGRAM
' --------------------------------------------------------
  CALL AnalogInput
'  -------------------------------------------------------
  END
' =======================================================================
'       SUBROUTINES
' -------------------------------------------------------------

END


DEFINT A-Z
  SUB AnalogInput
  SHARED a!, b!, c!, d!
   DO
    Channel$ = STR$(1)
    PRINT #1, "IA" + Channel$
    INPUT #1, value$
    counts$ = MID$(value$, 4)
    tEmp! = VAL(counts$)
    tCels! = a! + b! * tEmp!
    LOCATE 19, 4
    PRINT "Channel 1:   "; "Temperature ="; tEmp!; "counts"; tCels!; "degrees Ce
    Channel$ = STR$(2)
    PRINT #1, "IA" + Channel$
    INPUT #1, value$
    counts$ = MID$(value$, 4)
    pEmp! = VAL(counts$)
    ppsi! = c! + d! * pEmp!
    LOCATE 21, 4
    PRINT "channel 2:   "; "pressure =", pEmp!; "counts", ppsi!; "psi";
    SLEEP 2
    LOCATE 19, 4
    PRINT SPACE$(60);
    LOCATE 21, 4
    PRINT SPACE$(50)
```

```
  LOOP
END SUB

EFINT A-Z
SUB Handshake
  SHARED escapeCode$, recogCode$
  PRINT #1, escapeCode$ + recogCode$
  INPUT #1, response$
  LOCATE 3, 4
  PRINT "";
  LOCATE 4, 4
  PRINT "Handshake with Starbuck 8232-recognition code echo: `01:'";
  LOCATE 5, 4
  PRINT response$;
  LOCATE 6, 4
  PRINT "";
  CALL PauseTime
 END SUB

DEFINT A-Z
 SUB PauseTime
   LOCATE 25, 4
   PRINT " To continue, press andy key.";
   a$ = ""
   DO WHILE a$ = ""
    a$ = INKEY$
   LOOP
 END SUB

DEFINT A-Z
  SUB SetScreen
   SCREEN 9
   COLOR 14, 1
   LOCATE 1, 8
   PRINT "STAARBUCK 8232 ANALOG-DIGITAL CONVERTER";
   LOCATE 2, 8
   PRINT "IMMEDIATE COMMUNICATION MODE";
  END SUB
```

MEASUREMENT OF POISSON'S RATIO

by
Alan Cook and Jason Roelle
Students of Mechanical Engineering Technology

MECH 221
Mechanical Measurements with Computer Application

4/22/97

MEASUREMENT OF POISSON'S RATIO

CONTENTS

I. Objective

The purpose of experiment is to calculate Poisson's ratio from axial and lateral strain,√, for an aluminum beam and a steel beam. Poisson's ratio and the modulus of elasticity , E, are two fundamental elastic constants relating stress to strain in a two-dimensional stress field. A longitudinal and lateral strains, ε_x and ε_y are associated with the longitudinal and Lateral deformation, $\&_x$ and $\&_{y.}$ The deformation is caused by a load at the end which causes a uniform axial stress in the cantilever beam. In an uniaxially stress member, Poisson's ratio is equal to the ratio of lateral strain to axial strain.

II. APPARATUS

We will measure Poison's ratio by means of strain gauges aligned with the longitudinal and lateral axes on an uniaxially stresses member

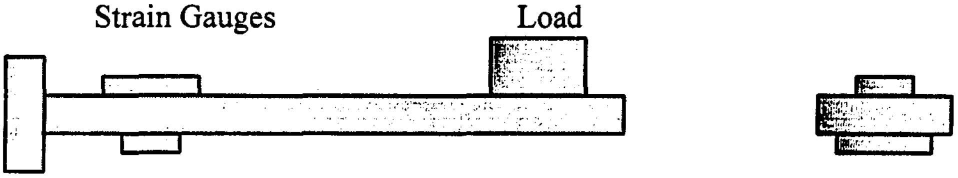


Figure 1. Aluminum and Steel with two strain gauges

III. EQUIPMENT

1. Cantilever flexure frame
2. One aluminum and steel beam, 1"*1/8*12-1/2"
3. Four single element strain gauges
4. Wheatstone bridge completion circuit
5. Strain indicator
6. Strain gage application materials, supplies and tools
7. Set of standard weight
8. Strain gauge information

Aluminum	Steel
CEA-13-240OUZ-120-GAUGE TYPE	EA-060060LZ-12--GAUGETYPE
120+-.3%-RESISTANCE	120=-.3%-RESISTANCE
2.120=-.5%-GAUGE FACTOR	2.04=-.5%-GAUGE FACTOR
(+0.6+-.2)%-TRANSVERSESENSITIVITY	(+1.0+-.2)%-TRANSVERSESENSITIVITY
R-A55AF500-LOT #	R-A38AD639-LOT#
0615116-6836-CODE	991117-CODE

IV. PROCEDURE

1. Install two strain gauges in a quarter-bridge circuit on the aluminum and steel cantilever with the bottom being perpendicular to the top.
2. Employ the "three-wire" method to achieve lead wire resistance compensation.
3. Read the axial strain at the midpoint of the gauge which is the average strain indicated by gauge one. This is because the axial strain varies linearly along the length of the cantilever beam.
4. read the lateral strain, measures by gauge 2,which is expected to be uniform across the central portion of the beam width.
5. Achieve a series of strain levels by placing standard weights in various combination near free end of the cantilever beam.
6. Place this data in a table with columns titled Trial #. Mass, $\varepsilon_{y,}$ and ε_x

V. EXPERIMENTAL OBSERVATION

We tested steel the first time. We found we could only go up to 1100 pounds because if we went any higher, the cantilever beam would hit the holder. We started at four hundred pounds in order to get bigger numbers for a better ratio. We started at four hundred pounds for the aluminum for the same reason. We could go up to two thousand pounds for the aluminum because it did not hit the holder. We also found that there was no outliers identified.

VI. SAMPLE CALCULATIONS

$$\varepsilon_1 = ((1-\surd_o K_t)/(1-K_t^2))*(\hat{e}_1 - K_t \hat{e}_2)$$

$$\varepsilon_2 = ((1-\surd_o K_t)/(1-K_t^2))*(\hat{e}_1 - K_t \hat{e}_2)$$

$$\surd = -(\varepsilon_y / \varepsilon_x)$$

$\hat{e}_1$,$\hat{e}_2$ = two observed but uncorrected orthogonal strains
ε_1, $\varepsilon_{2=}$ values corresponding to the corrected strains
Kt = transverse sensitivity of the strain gauges (see gauge data sheet)
$\surd_o$ = .285 (Poisson's ration for gauge calibration)=nu$_o$

Sx = Sample Standard Deviation STEV (list)
$t_{\alpha, n-1}$ = TINV (.05, 29)
Error in mean = Δxbar=(t_{n-1}, α_* Sx)/sqrt(n)
interval(xbar-error in mean, xbar+error in mean)

n = number of data points
α = degrees of freedom
n-1 = number of data points subtract one

number of intervals = 1+3*log(n)

VII. ERROR ANALYIS

We used 30 data points on the spread sheets for aluminum and steel. We found the average mean value or xbar to be .3278 and the published value to be .32 for aluminum. The error between the mean value and the published value came out to be 2.4 percent. We found the mean value to be .2728 and the published value to be .285 for steel. The error between the mean and the published value came out to be 4.3 percent.

VIII. RESULTS AND CONCLUSION

We used 30 data points for aluminum and steel. Our gauge constant was .005 aluminum and steel given by the gauge data sheet and our nu0 was .285 given by the handout. Our sample standard deviation Came out to be .0013 for aluminum and .0038 for steel. Our error in mean came out to be .128 percent for aluminum and .317 percent for steel. We used the equation given in this report to find the corrected ε_1 and ε_2. After we found Poisson's ration by taking e_y divided by e_x and then we sorted the values in order to make a bar chart. We used 6 intervals which we got from the equation 1+3 LOG10(n). Finally we used counted how many number were in each interval to get the frequency.

VIV. SUMMARY

This lab was useful to show the relationship between Poisson's ratio and the modulus of elasticity. This also gave us more practice in laying strain gauges. In this lab we used all thirty data points because there was no outliers and because we started the masses at 400 pounds which gave us a small percentages offset error. The values that we recorded for Poisson's ration on the aluminum and the steel came out relatively close with the text book values. Both of our graphs gave us a good example of what a student t-distribution graph should look like. Our average poison's ration for aluminum was.3278 and .2727 for steel. The 95 percent confidence interval value of Poisson's ratio was

[.327,.329] for aluminum which is a little high but still good. The 95 percent confidence interval value of Poisson's ratio was [.271, .274] for steel is a little low but still good.

VV. REFERENCES

1. Student Manual for Strain Gauge Technology, Bulletin 309D, Measurements Group, Inc., Raleigh, NC 1991

2. SB-10 Switch and Balance Unit Manual, Measurement Group, Inc., Raleigh, NC.

3. P-3500 Strain Indicator Manual, Measurement Group, Inc., Raleigh, NC.

4. Wolf, Lawrence J. , Statistics and Strengths of Materials: A Parallel Approach to Understanding Structures. Merril Publishing Company, Columbus, 1988. Pages 276-280 and 338-339.

5. E-101 Modulus of Elasticity-flexure, Vishay Experiments in Mechanics, Vishay Educational Products, Romulas MI.

6. Beckwith, Thomas G. , Marangoni, Roy D. , and Lienhard, John H. : Mechanical Measurements, Addison-wesley Publishing Company, Reading, Massachusetts, Fifth Edition, 1993. Chapter 3 and 12.

TABLE 2. Calibration Data

- Steel -

No.
CALIBRATION OF MEASUREMENT OF POISSON'S RATIO
MECH 221 2/12/97 Jason Roelle and Alan Cook

Trial no	Mass [grams]	Indicated Strains		Corrected Strains		Poisson's Ratio	Sorted values
		ey	ex	ey	ex		
		1.E-06	1.E-06	1.E-06	1.E-06		
1	400	27	99	26.79	98.89	0.2709	0.2659
2	450	31	112	30.76	111.87	0.2749	0.2669
3	500	34	123	33.73	122.86	0.2746	0.2681
4	600	41	149	40.68	148.83	0.2733	0.2683
5	700	47	174	46.63	173.81	0.2683	0.2695
6	800	54	199	53.57	198.78	0.2695	0.2696
7	900	62	227	61.51	226.75	0.2713	0.2705
8	1000	68	254	67.45	253.72	0.2659	0.2709
9	1100	77	275	76.41	274.69	0.2782	0.2709
10	1100	76	277	75.40	276.69	0.2725	0.2713
11	1000	69	250	68.46	249.72	0.2742	0.2715
12	900	62	225	61.52	224.75	0.2737	0.2723
13	800	56	200	55.57	199.77	0.2782	0.2724
14	700	48	172	47.63	171.81	0.2772	0.2725
15	600	41	149	40.68	148.83	0.2733	0.2731
16	500	34	123	33.73	122.86	0.2746	0.2731
17	450	31	112	30.76	111.87	0.2749	0.2732
18	400	27	99	26.79	98.89	0.2709	0.2733
19	400	28	100	27.78	99.89	0.2782	0.2733
20	450	31	112	30.76	111.87	0.2749	0.2737
21	500	34	124	33.73	123.86	0.2723	0.2742
22	600	41	150	40.68	149.83	0.2715	0.2746
23	700	48	175	47.62	174.81	0.2724	0.2746
24	800	55	200	54.57	199.78	0.2732	0.2749
25	900	61	226	60.51	225.75	0.2681	0.2749
26	1000	69	251	68.46	250.72	0.2731	0.2749
27	1100	76	279	75.40	278.69	0.2705	0.2772
28	1100	76	280	75.40	279.69	0.2696	0.2782
29	1000	69	251	68.46	250.72	0.2731	0.2782
30	900	61	227	60.51	226.75	0.2669	0.2782

Interval Midpoint	Frequency
0.267	2
0.269	4
0.271	5
0.273	9
0.275	6
0.277	4

Interval Midpoint	
0.267	.265-.268
0.269	.268-.270
0.271	.270-.272
0.273	.272-.274
0.275	.274-.276
0.277	.276-.278

n=	30	xbar Mean Value:		0.2727		5.4314
kt=	0.002	Sx Sample std Dev:		0.0031799	delta	0.0122969
nu0	0.285	Error in mean:		0.0011874	delta/12	0.00102474
05,29)=	2.0452	inerval:	0.271	0.274	delta/6	0.00204948

Error for published value= 4.3%
publishe value= 0.285

Error in mean= (t(.05,29)*Sx)/sqrt(n)
interval= (xbar-error in mean,xbar+error in mean)

Figure 3. Histogram of poisson's Ratio Data For Steel

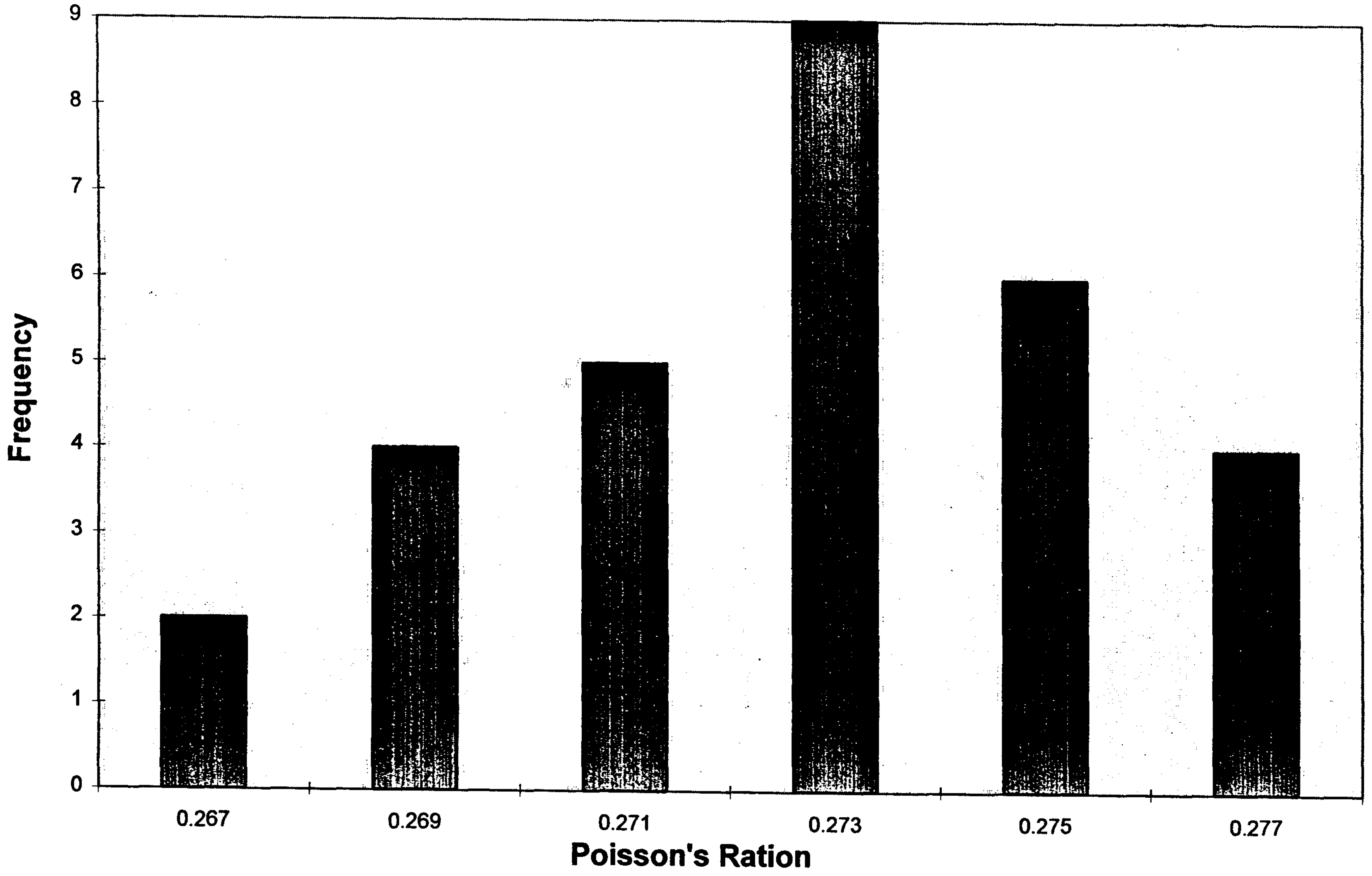


TABLE 1. Calibration Data

- Aluminum -

No.

CALIBRATION OF MEASUREMENT OF POISSON'S RATIO

MECH 221 2/12/97 Jason Roelle and Alan Cook

Trial no	Mass [grams]	Indicated Strains ey	Indicated Strains ex	Corrected Strains ey	Corrected Strains ex	Poisson's Ratio	Sorted values
		1.E-06	1.E-06	1.E-06	1.E-06		
1	400	33	101	32.78	100.88	0.3249	0.3208
2	450	37	113	36.75	112.86	0.3256	0.3214
3	500	41	124	40.73	123.85	0.3289	0.3225
4	600	50	152	49.67	151.81	0.3272	0.3234
5	700	58	175	57.62	174.79	0.3296	0.3247
6	800	66	200	65.56	199.75	0.3282	0.3249
7	900	76	226	75.51	225.72	0.3345	0.3249
8	1000	84	251	83.45	250.69	0.3329	0.3256
9	2000	165	497	163.91	496.39	0.3302	0.3256
10	2000	165	501	163.91	500.39	0.3276	0.3262
11	1000	82	249	81.46	248.70	0.3275	0.3271
12	900	75	223	74.51	222.72	0.3345	0.3272
13	800	66	199	65.56	198.76	0.3299	0.3275
14	700	57	173	56.62	172.79	0.3277	0.3276
15	600	49	150	48.67	149.82	0.3249	0.3277
16	500	40	123	39.73	122.85	0.3234	0.3277
17	450	37	112	36.76	111.86	0.3286	0.3282
18	400	32	99	31.78	98.88	0.3214	0.3286
19	400	32	98	31.79	97.88	0.3247	0.3289
20	450	36	111	35.76	110.87	0.3225	0.3289
21	500	40	124	39.73	123.85	0.3208	0.3296
22	600	49	147	48.68	146.82	0.3316	0.3299
23	700	57	173	56.62	172.79	0.3277	0.3299
24	800	66	199	65.56	198.76	0.3299	0.3302
25	900	74	225	73.51	224.72	0.3271	0.3302
26	1000	82	250	81.45	249.69	0.3262	0.3309
27	2000	166	500	164.91	499.39	0.3302	0.3316
28	2000	166	499	164.91	498.39	0.3309	0.3329
29	1000	82	248	81.46	247.70	0.3289	0.3345
30	900	73	223	72.51	222.73	0.3256	0.3345

Interval Midpoint	Frequency
0.322	3
0.324	4
0.327	9
0.329	7
0.331	4
0.333	3

Interval Midpoint	
0.322	.320-.323
0.324	.323-.3255
0.327	.3255-.328
0.329	.328-.330
0.331	.330-.332
0.333	.332-.335

n=	30	xbar	Mean Value:		0.3278		5.4314
kt=	0.002	Sx	Sample std Dev:		0.0034368	delta	0.0137603
nu0	0.285		Error in mean:		0.0012833	delta/12	0.0011467
t(.05,29)=	2.0452		ierval:	0.327	0.329	delta/6	0.0022934

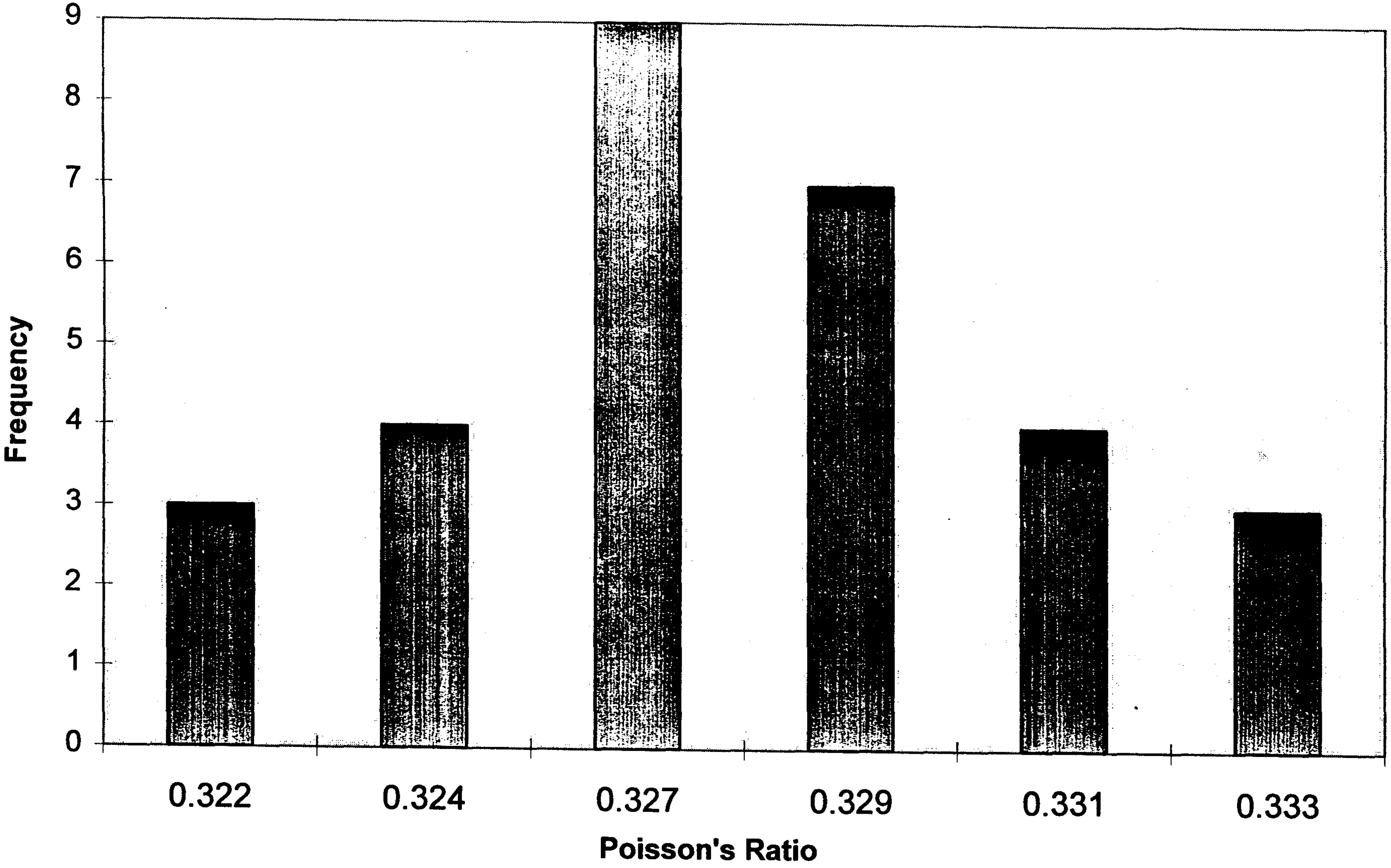
Error for published value= -2.4%

published value= 0.32

Error in mean= (t(.05,29)*Sx)/sqrt(n)

interval= (xbar-error in mean,xbar+error in mean)

Figure 2. Histogram Of Poisson's Ratio Data For Aluminum



AREO DRAG MEASUREMENT FOR MODEL CAR

MECH 221
Mechanical Measurements with Computer Data Acquisition

Mechanical Engineering Technology Program
Ferris State University

April 28, 1997

by

Darrell Rodriguez
Mattew Crosson
Brent Lavigne

MECH 221 AREO DRAG MEASUREMENT

SUMMARY

A model car, made of wood, was placed in a wind tunnel to find the drag strain and drag coefficient. Using a strain gage force balance to find the drag in micro strain, which was calibated to 200 micro strain = to 2 pounds. After finding the micro strain the throttle position of the wind tunnel was moved one centimeter for thirty centimeters. Then using a spreadsheet the Drag coefficient and Reynolds number were found.

The Drag coefficient was calculated by Fd/(1/2ρV^2A).

MECH 221 AREO DRAG MEASUREMENT

CONTENTS

MECH 221 AREO DRAG MEASUREMENT

OBJECTIVE

The objective of this experiment was to calculate the drag coefficient using a wind tunnel and recording the micro-strain with a strain gage force balance.

APPARATUS

The apparatus, as diagammed in Figure 1, consisted of the follwing components.

1. Wind tunnel in Swan lab 304.
2. Strain gage.
3. Strain gage force balance
4. Model car.

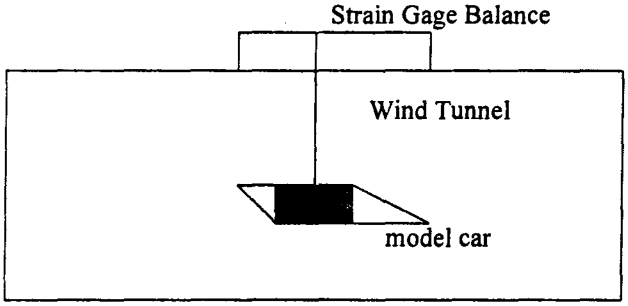


Figure 1. Wind Tunnel with Apparatus

PROCEDURE

1. Attach the strain gage apparatus to the wind tunnel.
2. Connect gage wires to micro-strain readout.
3. Calibrate readout to lbs. Scale.
4. Attach model car to strain gage apparatus.
5. Turn on wind tunnel and record micro-strain.
6. Open wind tunnel one cm and record.
7. Repeat step 6 to 30 cm.

MECH 221 AREO DRAG MEASUREMENT

EXPERIMENTAL OBSERVATIONS

1. During the testing there was lots of vibrations in the strain gage force balance.
2. The micro strain was hard to read from the vibration.
3. The Drag coefficient may not have came out correct.

CALCULATIONS

The main calculations were the Drag coefficient and Reynolds number.

$$Cd = Fd/(1/2\rho V^{\wedge}2A)$$

$$ReD = \rho DV/\mu$$

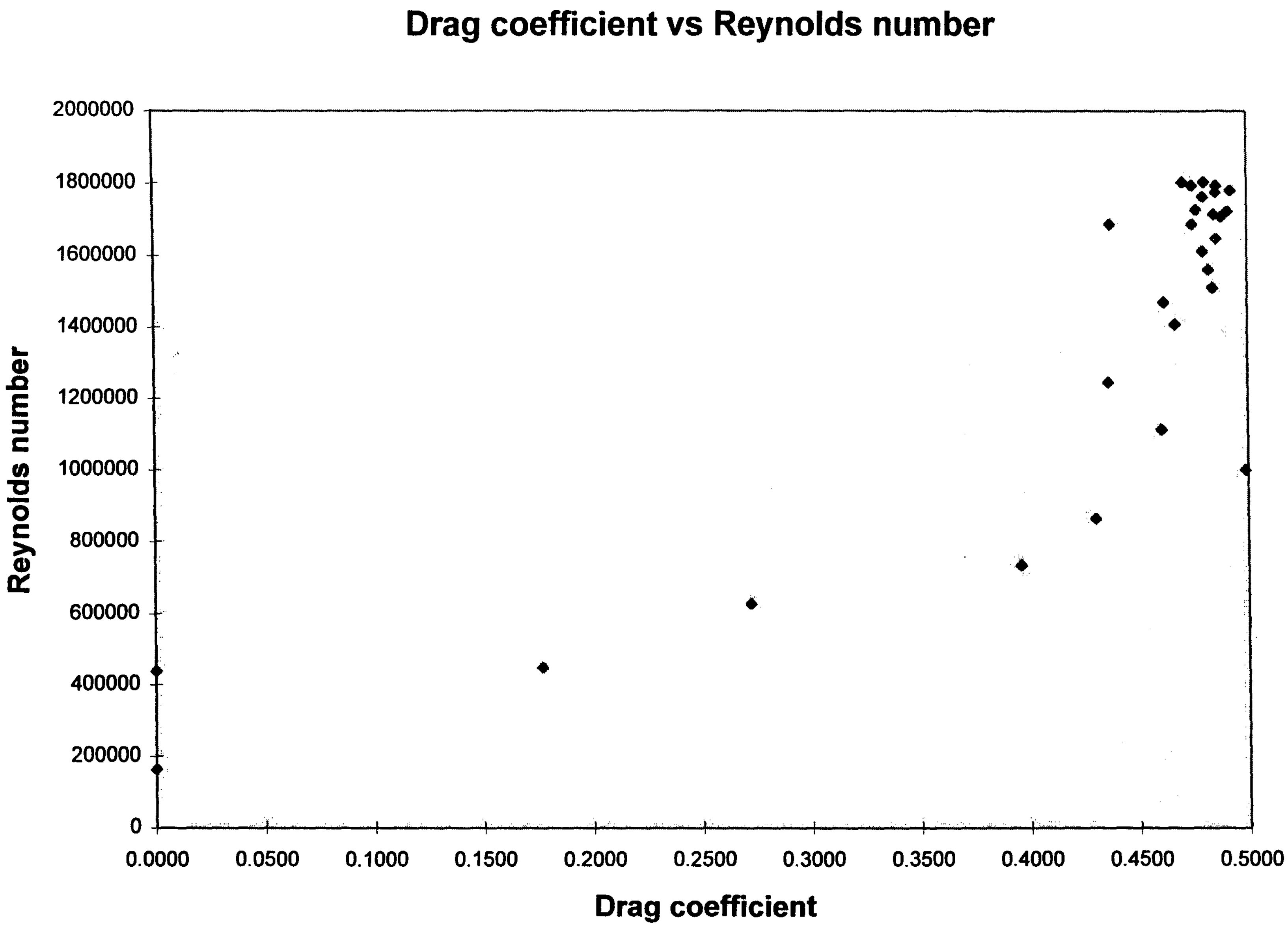
RESULTS AND CONCLUSION

1. The Drag coefficient gather on the chart as the Reynolds number increases showing the higher the Reynolds number the more uniformed the Drag coefficient.
2. The more the throttle position increases the higher the Reynolds number.
3. The more the throttle opens the more uniformed the Drag coefficient becomes.

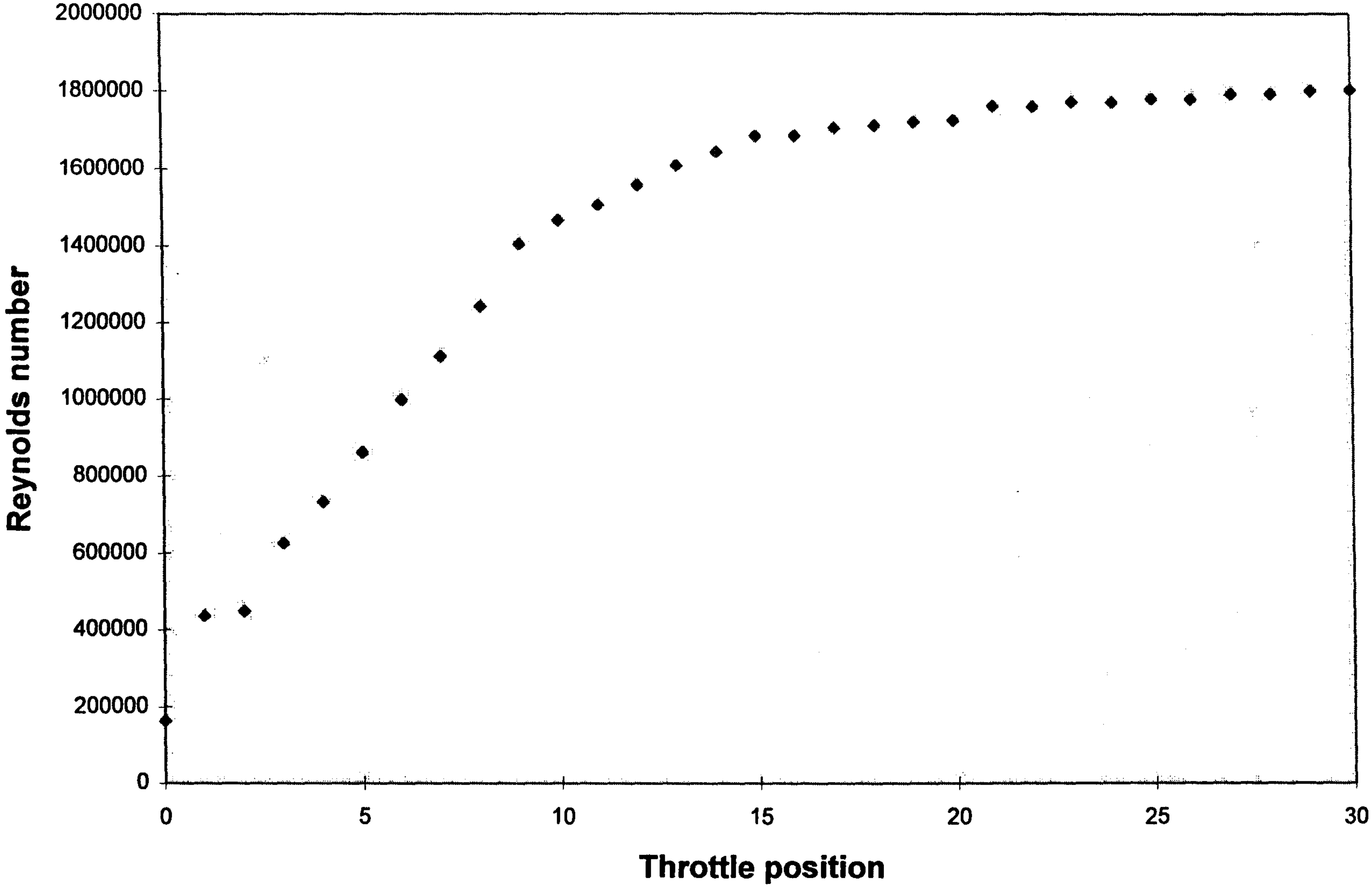
REFRENCES

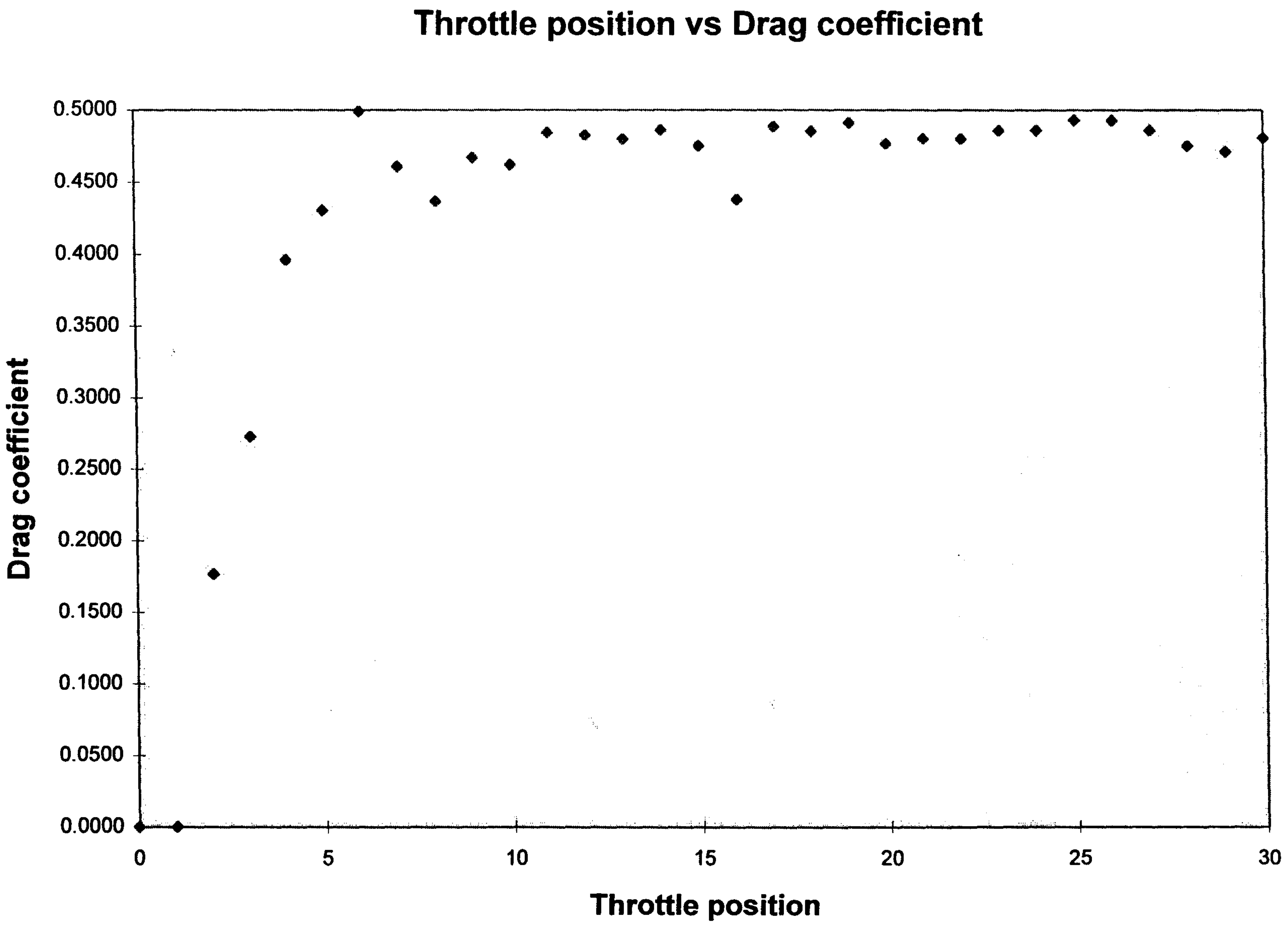
1. Mechanical Measurements text
2. Microsoft Excel

Humidity =	50%	Barimetric				200 microstrain = 2 lbs			Dynamic	
Temp. =	74 F	pressure =	29.8	(inches of mercury)		Area =	0.036458	ft^2	Viscosity	
RHO =	0.002309	slugs/ft^3				Length =	7.5 inches		3.78E-07	lbs/ft^2
	Throttel		Pitot tube			Strain gage				
Trial	Position		(inches of	Velocity	Velocity	Drag	Drag	Dynamic	Reynolds	
No.	(cm)	Micro strain	water)	(ft/min)	(ft/sec)	(lbs)	Coefficient	Velocity	Number	
0	0	0	0.04	805	13	0.00	0.0000	0.2078	163910	
1	1	0	0.28	2140	36	0.00	0.0000	1.4687	435737	
2	2	1	0.30	2200	37	0.01	0.1767	1.5522	447954	
3	3	3	0.58	3070	51	0.03	0.2722	3.0225	625100	
4	4	6	0.80	3600	60	0.06	0.3960	4.1562	733016	
5	5	9	1.11	4230	71	0.09	0.4302	5.7382	861294	
6	6	14	1.48	4900	82	0.14	0.4987	7.6999	997716	
7	7	16	1.84	5450	91	0.16	0.4607	9.5254	1109705	
8	8	19	2.30	6100	102	0.19	0.4367	11.9330	1242055	
9	9	26	2.90	6900	115	0.26	0.4671	15.2683	1404947	
10	10	28	3.20	7200	120	0.28	0.4620	16.6248	1466032	
11	11	31	3.40	7400	123	0.31	0.4842	17.5612	1506755	
12	12	33	3.60	7650	128	0.33	0.4823	18.7678	1557659	
13	13	35	3.85	7900	132	0.35	0.4797	20.0145	1608563	
14	14	37	4.00	8070	135	0.37	0.4859	20.8852	1643177	
15	15	38	4.20	8270	138	0.38	0.4752	21.9332	1683900	
16	16	35	4.20	8270	138	0.35	0.4377	21.9332	1683900	
17	17	40	4.30	8370	140	0.40	0.4883	22.4669	1704262	
18	18	40	4.37	8400	140	0.40	0.4849	22.6282	1710370	
19	19	41	4.40	8450	141	0.41	0.4911	22.8984	1720551	
20	20	40	4.44	8470	141	0.40	0.4769	23.0069	1724623	
21	21	42	4.60	8650	144	0.42	0.4801	23.9952	1761274	
22	22	42	4.60	8650	144	0.42	0.4801	23.9952	1761274	
23	23	43	4.63	8700	145	0.43	0.4859	24.2734	1771455	
24	24	43	4.63	8700	145	0.43	0.4859	24.2734	1771455	
25	25	44	4.70	8740	146	0.44	0.4927	24.4971	1779600	
26	26	44	4.70	8740	146	0.44	0.4927	24.4971	1779600	
27	27	44	4.75	8800	147	0.44	0.4860	24.8346	1791817	
28	28	43	4.75	8800	147	0.43	0.4749	24.8346	1791817	
29	29	43	4.77	8840	147	0.43	0.4706	25.0609	1799961	
30	30	44	4.78	8850	148	0.44	0.4805	25.1176	1801997	


Drag coefficient vs Reynolds number
Reynolds number
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
0.0000
0.0500
0.1000
0.1500
0.2000
0.2500
0.3000
0.3500
0.4000
0.4500
0.5000
Drag coefficient

Throttle position vs Reynolds number




Throttle position vs Drag coefficient
0.5000
0.4500
0.4000
0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
Drag coefficient
0
5
10
15
20
25
30
Throttle position

Strain vs Vertical Deformation of a Cantilever Beam

MECH 221
Mechanical Measurements with Computer Data Acquisition

Mechanical Engineering Technology Program
Ferris State University

April 27, 1997

by

Matthew M. Crosson
Brent Lavigne
Darrell Rodriguez
Group #7

Summary

A vertical deformation was imposed on an aluminum cantilever beam and the strain along with the amount of deformation was recorded. This was repeated 30 times at various amounts of deflection. The experimental hypothesis for the strain as a function of vertical deflection is

$$\varepsilon = a + b^* y$$

where a=0, and b= $6L_2h/4L_o^3$

After reducing the data by means of Microsoft Excel spreadsheet, the regression analysis gave the following equation

Strain = -7.1763 + 1803.3*Vertical Deflection

R Squared = 0.999 8

Note that R Squared is the square of the correlation coefficient. There was drift apparent over time while taking data, yet there were no outliers in the data points so the data were consistent.

MECH 221 STRAIN VS VERTICAL DEFORMATION FOR A CANTILEVER BEAM

TABLE OF CONTENTS

MECH 221 STRAIN VS VERTICAL DEFORMATION FOR A CANTILEVER BEAM

I. OBJECTIVE

The objective of this experiment was to impose a vertical deformation on an aluminum cantilever beam, record the strain and the amount of deflection that was imposed, and reduce the data to show that strain is a function of the vertical deformation on a cantilever beam.

II. APPARATUS

The apparatus, as diagrammed in Figure 1, consisted of the following component parts.

1. Cantilever flexure frame with a micrometer barrel and thimble for imposing the deformation.
2. Aluminum cantilever beam
3. Micro-Measurements SB-10 switch and balance unit
4. Micro-Measurements P-3500 strain indicator

III. PROCEDURE

The experiment was executed in the following manner

1. Install strain gage per instructions in Micro-Measurements Student Manual for Strain Gage Technology
2. Place aluminum cantilever beam into the cantilever flexure frame
3. Connect the strain gage to the SB-10 switch and balance unit using a quarter bridge circuit
4. Impose a deflection on the end of the aluminum cantilever beam
5. Record the deflection that was imposed and the strain as indicated on the P-3500 strain indicator
6. Repeat with 3 cycles and 10 data points per cycle.

IV. EXPERIMENTAL OBSERVATIONS

There was a small hint of drift in the indicator after the imposed deflection was removed. The initial reading for the zero deformation point was zero, after all data points were taken the reading for the zero deformation point was -2. There are a number of places where error could have taken place in this experiment. Errors could have taken place in the measurement of the dimensions of the cantilever beam, in the deflection that was imposed, and the measurement of the length from the cantilever flexure frame to the gage and to the spot of the deformation.

V. CALCULATIONS

The Strain -Vs- Vertical Deformation data were reduced by means of Microsoft Excel spreadsheet. The linear regression function was used to find the least squares fit to the data and the results were presented in the accompanying graph.

The regression calculations give

$$\text{Strain} = 1803.3*\text{Vertical Deformation} - 7.1763$$

$$\text{R Squared} = 0.999\,8$$

The same calculations were also done for the calculated value for strain, for the Force vs measured and calculated values of strain, and the Force vs Vertical Deformation. Those values can be obtained from the accompanying graphs.

VI. ERROR ANALYSIS

The error obtained in this experiment can be found in the measurements taken for the dimensions of the aluminum beam and the length associated with the strain and vertical deformation. The values of length that were determined had standard deviations about the mean values as follows

(Lo)	S=0.009 87
(L1)	S=0.003 2
(L2)	S=0.009 47
(B)	S=0.001 59
(H)	S=0.000 98

These deviations gave intervals as follows

(Lo)	10.075 4 ± 0.007 06
(L1)	3.036 6 ± 0.002 29
(L2)	7.038 8 ± 0.006 78
(B)	0.995 75 ± 0.001 13
(C)	0.188 8 ± 0.000 7

VII. RESULTS AND CONSLUSIONS

The data for the strain and vertical deformation is presented in the accompanying spreadsheets and graphs, the primary results and conclusions are as follows

1. The strain imposed in a cantilever beam is a function of the force that is present.
2. The strain is a function of the vertical deflection of a cantilever beam
3. The force that is present is a function of the vertical deformation
4. There are no apparent outliers. Therefore, the data is consistent.

5. A drift of the strain indicator was noted on the last data point with an imposed deflection of zero, the strain indicator read a strain of -2 microstrains.

VIII. REFERENCES

1. Statics and Strengths of Materials
2. Micro-Measurements Student Manual for Strain Gage Technology

Strain vs. Deformation for a Cantilever Beam

Dimensions for Aluminum Cantilever Beam							
L_o	Base	Height		L_1	L_2		
(in)	(in)	(in)		(in)	(in)		
10.1	1	0.191		3.038	7.062		
10.08	0.995	0.189		3.04	7.04		
10.08	0.995	0.189		3.033	7.047		
10.067	0.995	0.1885		3.033	7.034		
10.067	0.996	0.1875		3.038	7.029		
10.07	0.9945	0.189		3.038	7.032		
10.075	0.995	0.1875		3.04	7.035		
10.07	0.996	0.1885		3.033	7.037		
10.075	0.996	0.189		3.04	7.035		
10.07	0.995	0.189		3.033	7.037		
10.0754	0.99575	0.1888		3.0366	7.0388		
$I=bh^3/12$		I=	0.00056	in^4			
c=h/2		c=	0.0944	in			
$E_{aluminum}$=	1.06E+07	psi					

Strain vs. Deformation for a Cantilever Beam

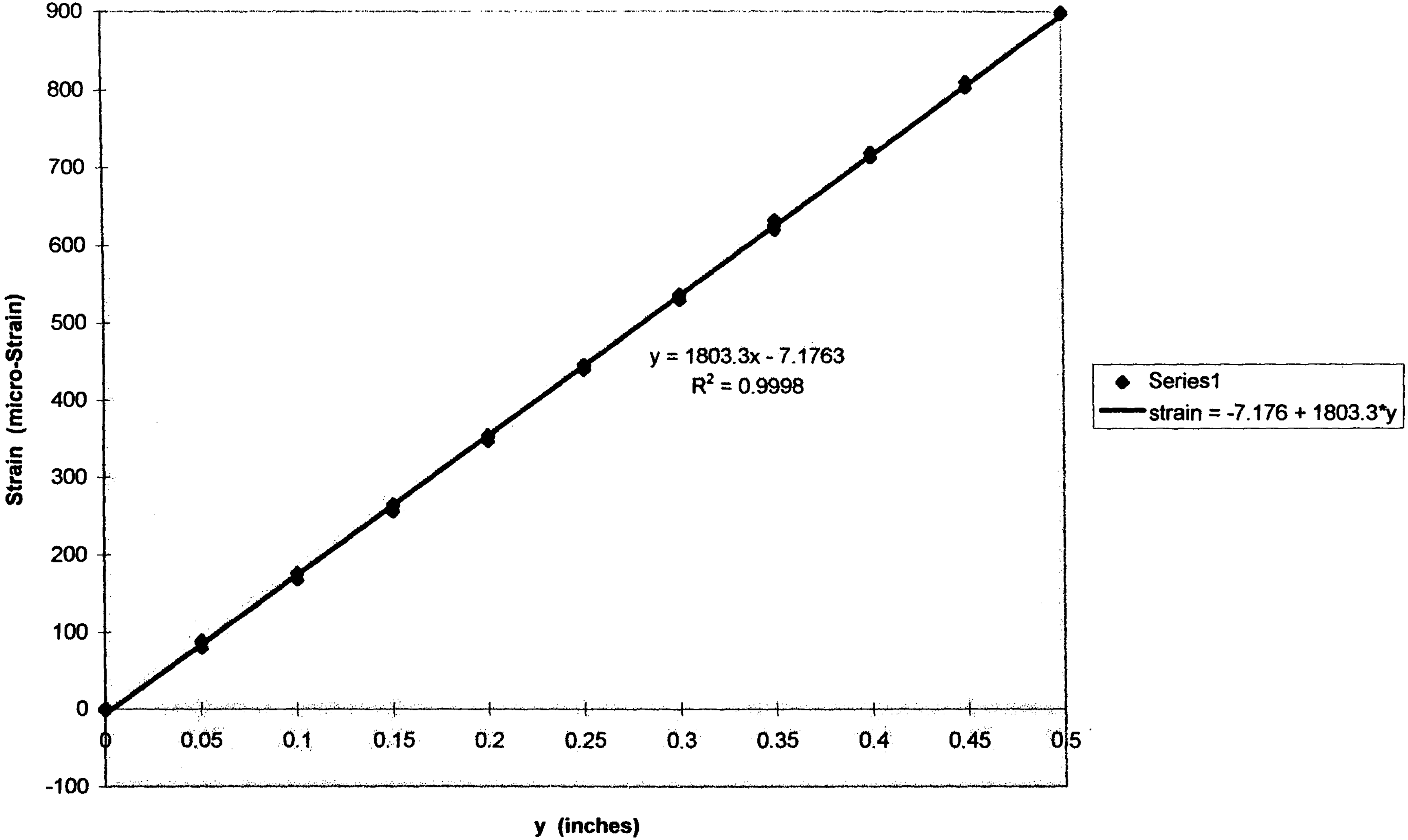
Group #7 Matt Crosson, Darrell Rodriguez, Brent Lavigne

Data Points			Calculated values		
y_o (in)	strain (uS)		F_o (lbf)	Stress (psi)	Strain (uS)
0	0		0	0	0
0.05	88		88.1272	104859	97
0.1	175		176.254	209718	195
0.15	264		264.382	314577	292
0.2	354		352.509	419436	390
0.25	445		440.636	524295	487
0.3	535		528.763	629154	585
0.35	625		616.89	734013	682
0.4	712		705.017	838871	780
0.45	802		793.145	943730	877
0.5	897		881.272	1048589	974
0.05	86		88.1272	104859	97
0.1	175		176.254	209718	195
0.15	262		264.382	314577	292
0.2	352		352.509	419436	390
0.25	444		440.636	524295	487
0.3	533		528.763	629154	585
0.35	632		616.89	734013	682
0.4	719		705.017	838871	780
0.45	810		793.145	943730	877
0.5	899		881.272	1048589	974
0.45	802		793.145	943730	877
0.4	712		705.017	838871	780
0.35	619		616.89	734013	682
0.3	528		528.763	629154	585
0.25	438		440.636	524295	487
0.2	346		352.509	419436	390
0.15	255		264.382	314577	292
0.1	167		176.254	209718	195
0.05	79		88.1272	104859	97
0	-2		0	0	0

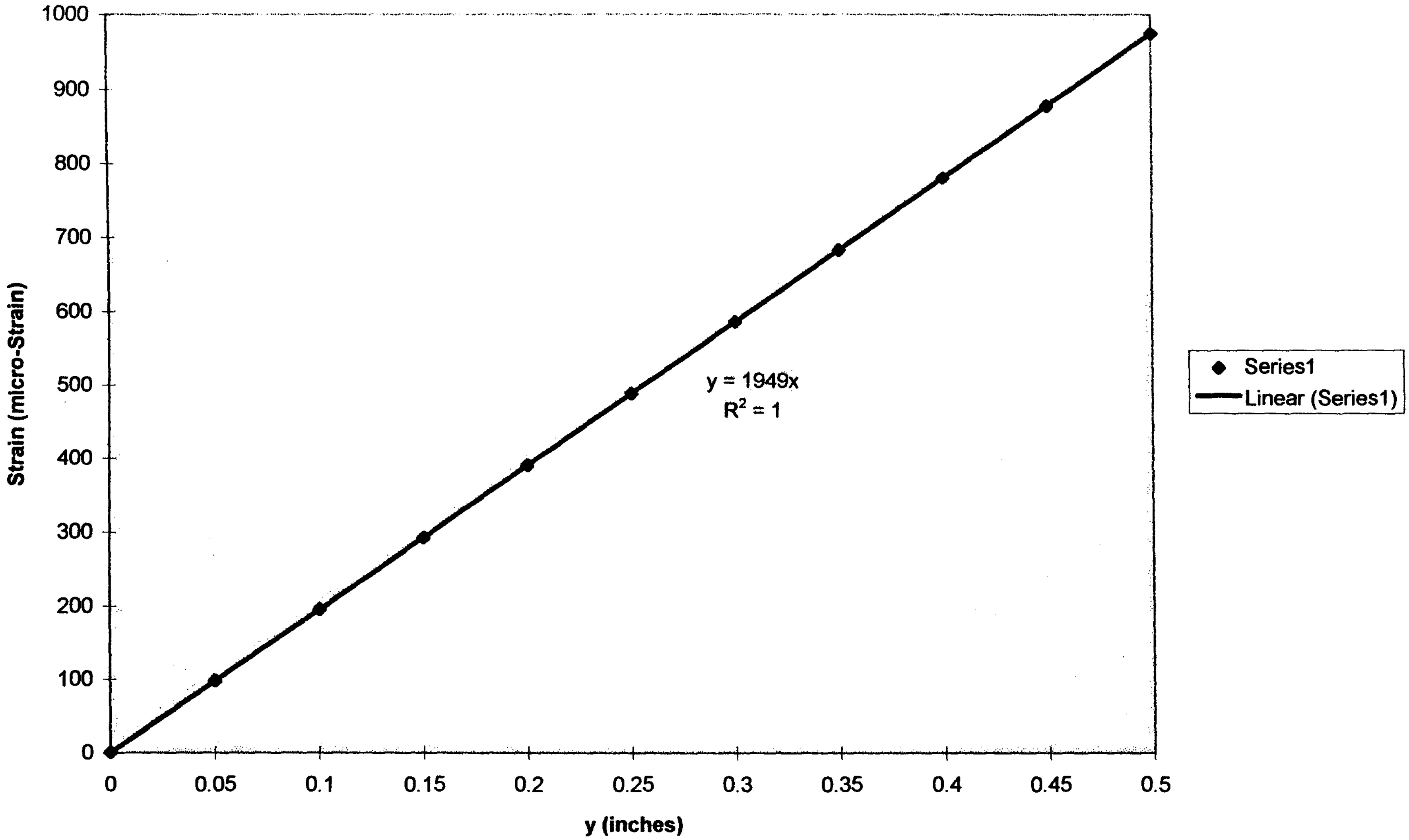
a=y-intercept	a=	-7.1763		a=y-intercept	a=	0
b=slope	b=	1803.29		b=slope	b=	1948.97
measured values				Calculated values		
strain = -7.176 + 1803.3*y_o		chart 1		strain = 0 + 1949*y_o		chart 2

	Strain vs Deformation for a Cantilever Beam						
Group #7		Matt Crosson, Darrell Rodriguez, Brent Lavigne					
Lo			L1			L2	
(inches)			(inches)			(inches)	
n=	10		n=	10		n=	10
nu=	9		nu=	9		nu=	9
t=	2.26216		t=	2.26216		t=	2.26216
S_{Lo}=	0.00987		S_{L1}=	0.0032		S_{L2}=	0.00947
L_{obar}=	10.0754		L_{1bar}=	3.0366		L_{2bar}=	7.0388
delta $_{Lo}$=	0.00706		delta $_{L1}$=	0.00229		delta $_{L2}$=	0.00678
Base			Height				
(inches)			(inches)				
n=	10		n=	10			
nu=	9		nu=	9			
t=	2.26216		t=	2.26216			
S_B=	0.00159		S_H=	0.00098			
B_{bar}=	0.99575		H_{bar}=	0.1888			
delta B=	0.00113		delta H=	0.0007			

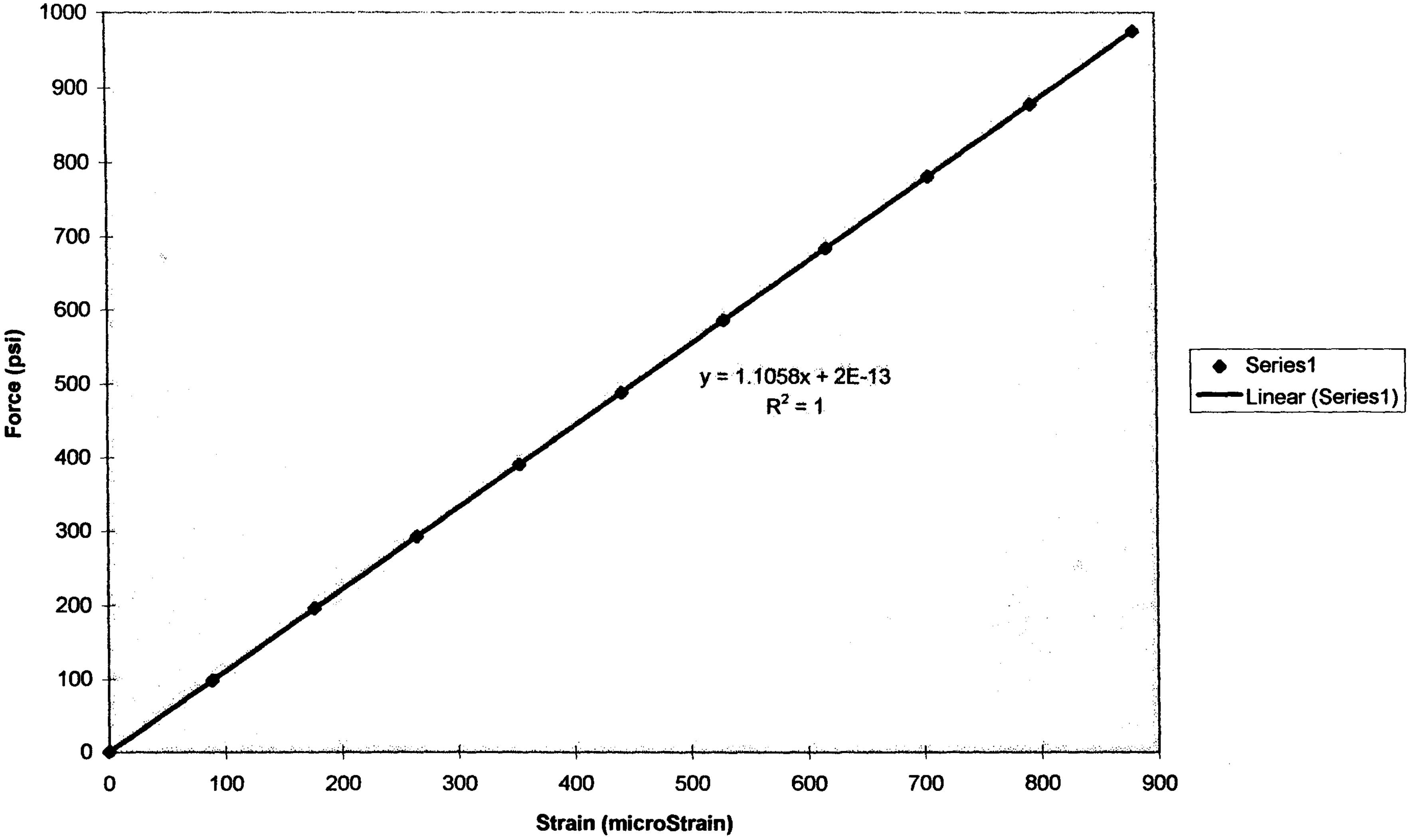
Strain vs. Vertical Deformation of a Cantilever Beam



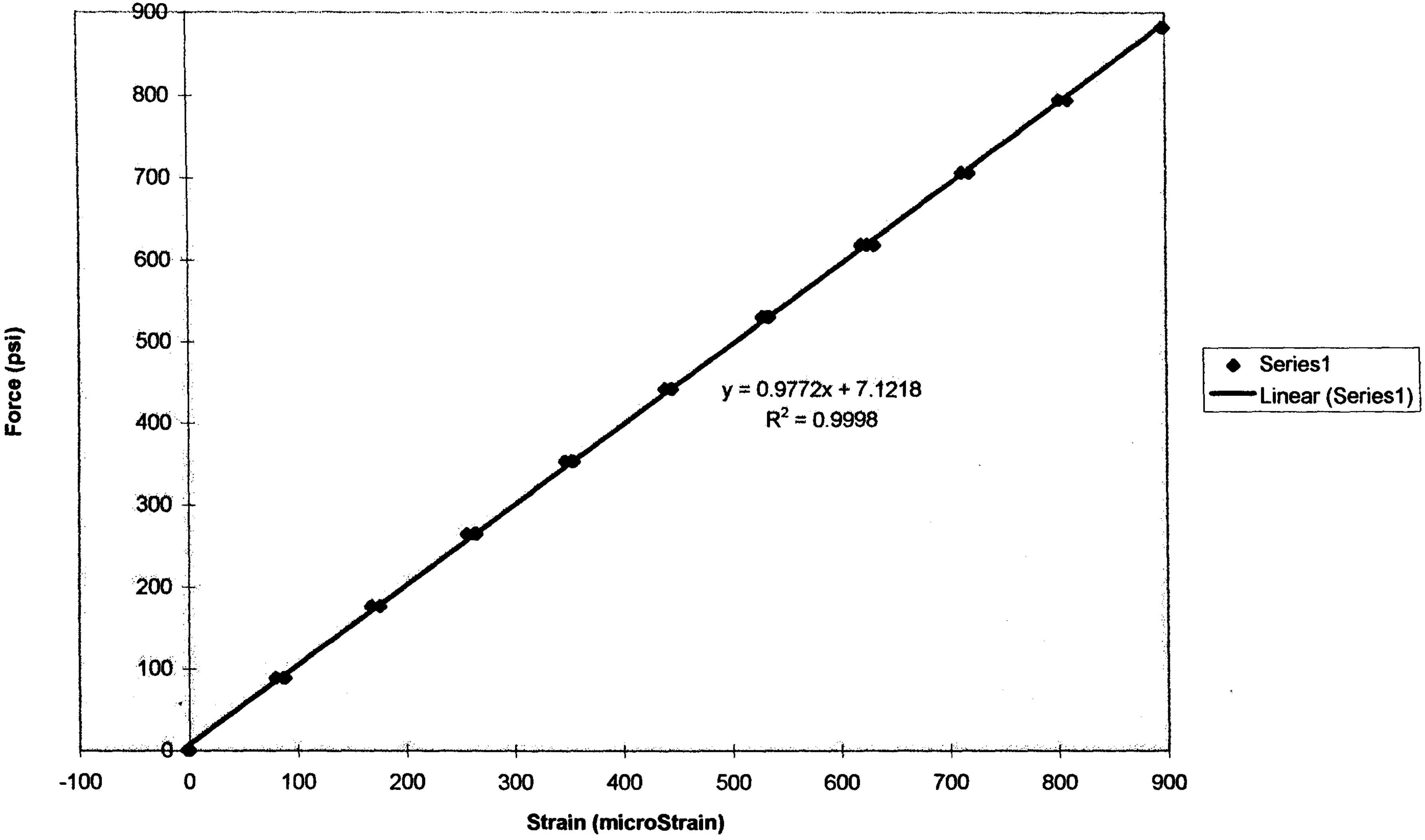
Strain vs Vertical Deformation of a Cantilever Beam



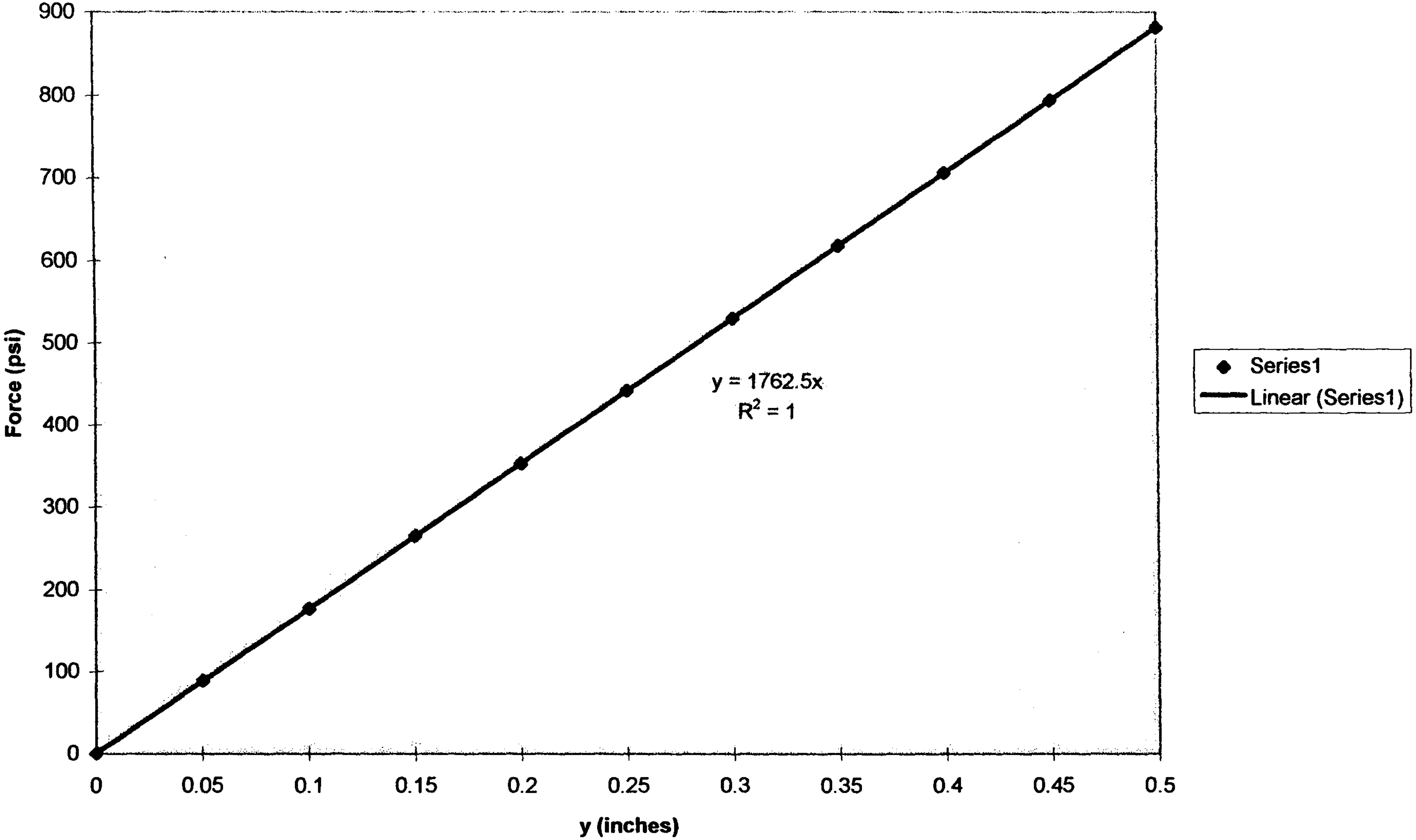
Force vs Strain for a Cantilever Beam



Force vs Strain for a Cantilever Beam



Force vs Vertical Deformation for a Cantilever Beam



STEEL VIBRATING BEAM

MECH 221
Mechanical Measurements with Computer Applications

Mechanical Engineering Technology Program
Ferris State University

April 30, 1997

by

J. R. Harral
&
B. Rockhold

SUMMARY

The purpose of this lab is to measure the frequency and period of an metal alloy and compare the measured values to the computed values. We also computed the spring constant, and the angular velocity of the beam.

The spring constant is:

$$k = (Ebh^3)/(4l_o^3)$$

The angular velocity of the beam:

$$\omega = \sqrt{(k / m)}$$

The frequency of the metal beam is the cycles per unit time.

$$f = \omega/2\Pi$$

Finally, the period, τ, of vibration is.

$$\tau = 2\Pi / \sqrt{(Ebh^3/4mL_o^3)} = 2\Pi / \sqrt{(k/m)}$$

CONTENTS

DATA GRAPH

SPREADSHEET

I. OBJECTIVE

The purpose of this experiment is to measure the frequency and period of a metal cantilever beam. Then to calculate the spring constant and angular velocity.

II. APPARATUS

- Cantilever flexure frame
- Metal beam, 3/16 x 1 x 12 1/2 inches
- Strain gage suitable for metal (EA-06-060LZ-120)
- Strain gage application kit and supplies
- Temperature-controlled soldering iron and soldering supplies
- Micrometer with venire scale
- Engineering scale
- Set of precision gram masses
- Whetstone bridge completion circuit and strain indicator
- Starbuck 8232 analog-digital converter

III. PROCEDURE

- Trim an metal strip (0.100" x .905") to a length of 12.25" and file smooth
- Measure and record the length and thickness of the metal beam with venire calipers.
- Prepare the beam for attaching a strain gage[1].
- Prepare the strain gage to be bonded[2].
- Solder lead wires to strain gage[3].
- Measure all points, L, L_0, L1, L2, L3, h, b, and L_s[4]
- Clamp beam fixture.
- Connect the three gage lead wires to the starbuck 8232 analog-digital converter.
- Make 5 weight distributions of 50g, 100g, 200g, 300g, 400g, and 500g.
- Make 3 weight placements of 500g at points every 2 in. from the end.
- Record a frequency response graph using the starbuck 8232 analog-digital converter.

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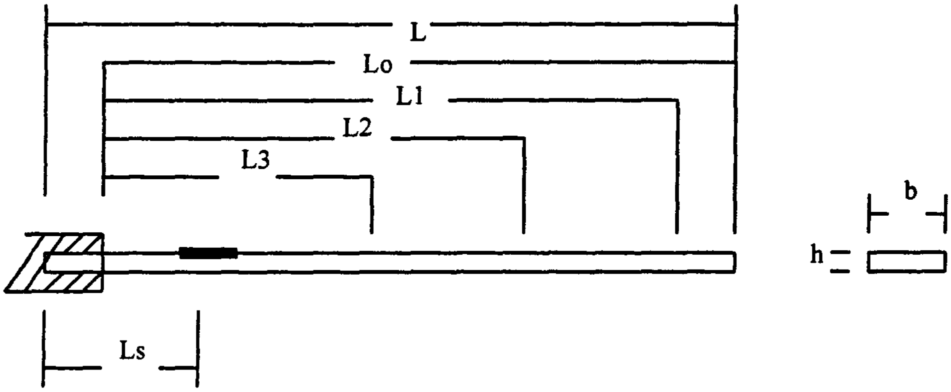
[1] REFER TO "STUDENT MANUAL FOR STRAIN GAGE TECHNOLOGY" (SECTION 3.0 -3.3)
[2] REFER TO "STUDENT MANUAL FOR STRAIN GAGE TECHNOLOGY" (SECTION 4.0-4.3)
[3] REFER TO "STUDENT MANUAL FOR STRAIN GAGE TECHNOLOGY" (SECTION 5.0)
[4] SEE ATTACHED DIAGRAM WITH MEASUREMENTS


L
Lo
L1
L2
L3
b
h
Ls

IV. EXPERIMENTAL OBSERVATIONS

The sensitivity of the strain gage is very high, reset the analog-digital converter every time the mass changes weight or position. A improper reading will occur if the beam fixture is not stable or held down.

V. CALCULATIONS

Theoretical period:

$$\tau = (2\pi) / \sqrt{(k/m)}$$

Theoretical frequency:

$$f = (\sqrt{(k/m)}) / (2\pi)$$

Spring constant:

$$k = (Ebh^3)/(4l_o^3)$$

Angular velocity:

$$\omega = \sqrt{(k / m)}$$

VI. ERROR ANALYSIS

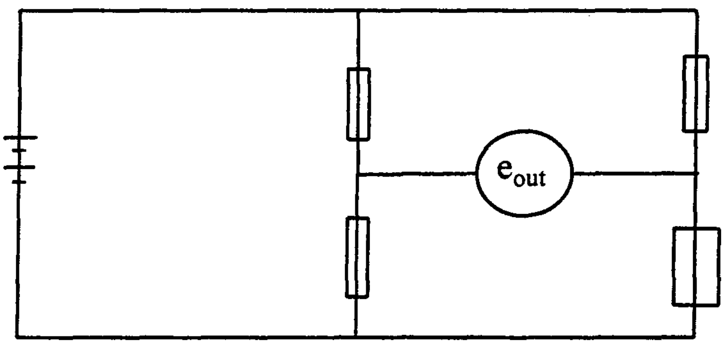
Several errors will occur if the strain gage is not properly attached, these are:
1. A low total resistance. 2. No reading on strain indicator - loose wire.
If pressure is applied to the table the test is occupying the strain indicator will read an error. The error in the strain gage is (+1.0 ± 0.2)%.

VII. RESULTS AND CONCLUSIONS

The period of oscillation for the metal beam theoretical had a 2% margin of error.

See accompanying spreadsheet and graphs.

WHEATSTONE BRIDGE

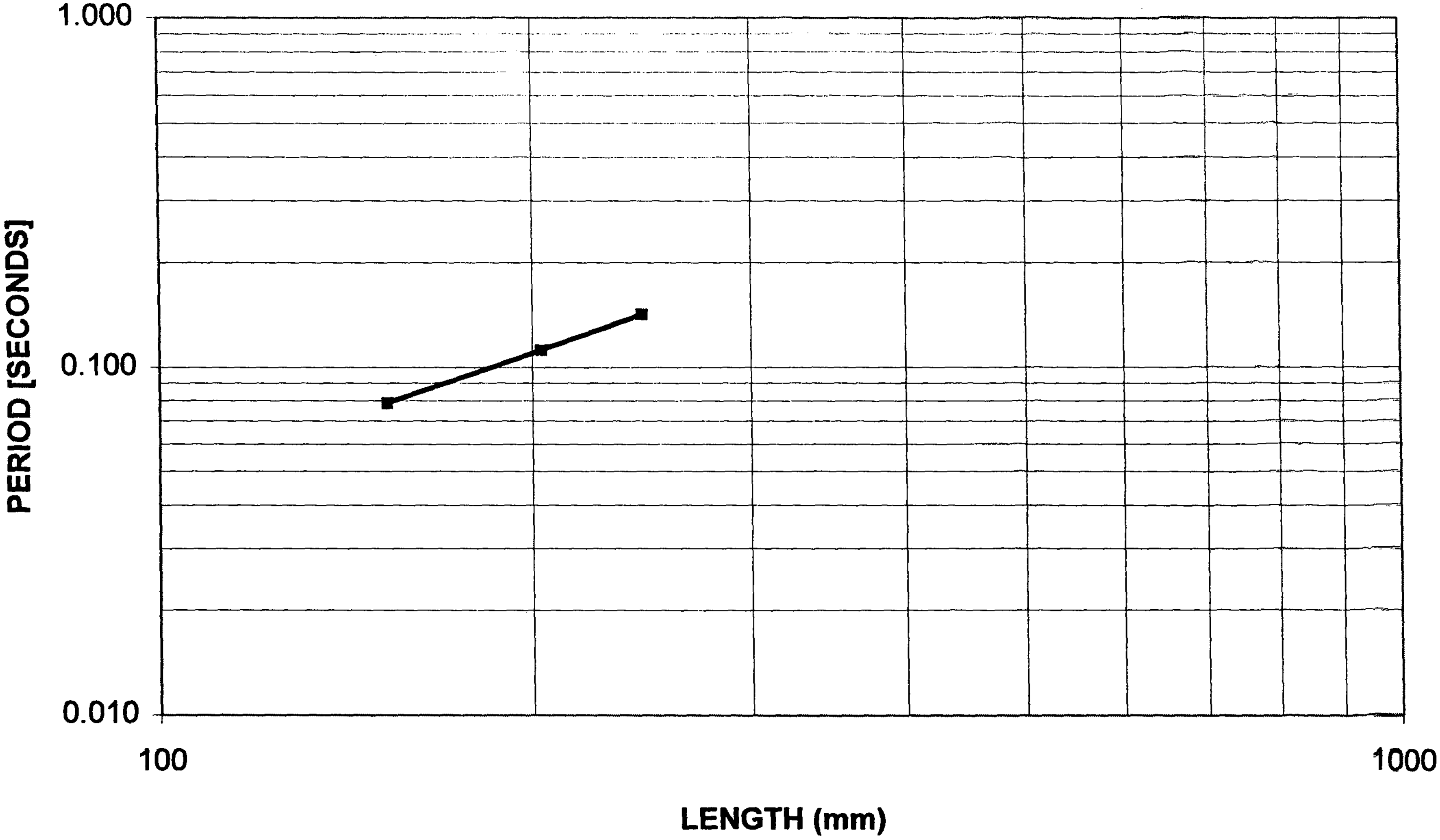


trial no.	mass (grams)	peaks	time (sec)	frequency (peaks/sec)	actual period (sec/peak)	theoretical period (sec/peak)	theoretical frequency (peaks/sec)	weight comp. frequency (peaks/sec)
1	50	15	0.875	17.1	0.058	0.041	24.7	16.8
2	100	12	0.875	13.7	0.073	0.057	17.5	14.1
3	200	9	0.845	10.7	0.094	0.081	12.3	11.2
4	300	8	0.915	8.7	0.114	0.099	10.1	9.6
5	400	6	0.77	7.8	0.128	0.115	8.7	8.5
6	500	5	0.702	7.1	0.140	0.128	7.8	7.7

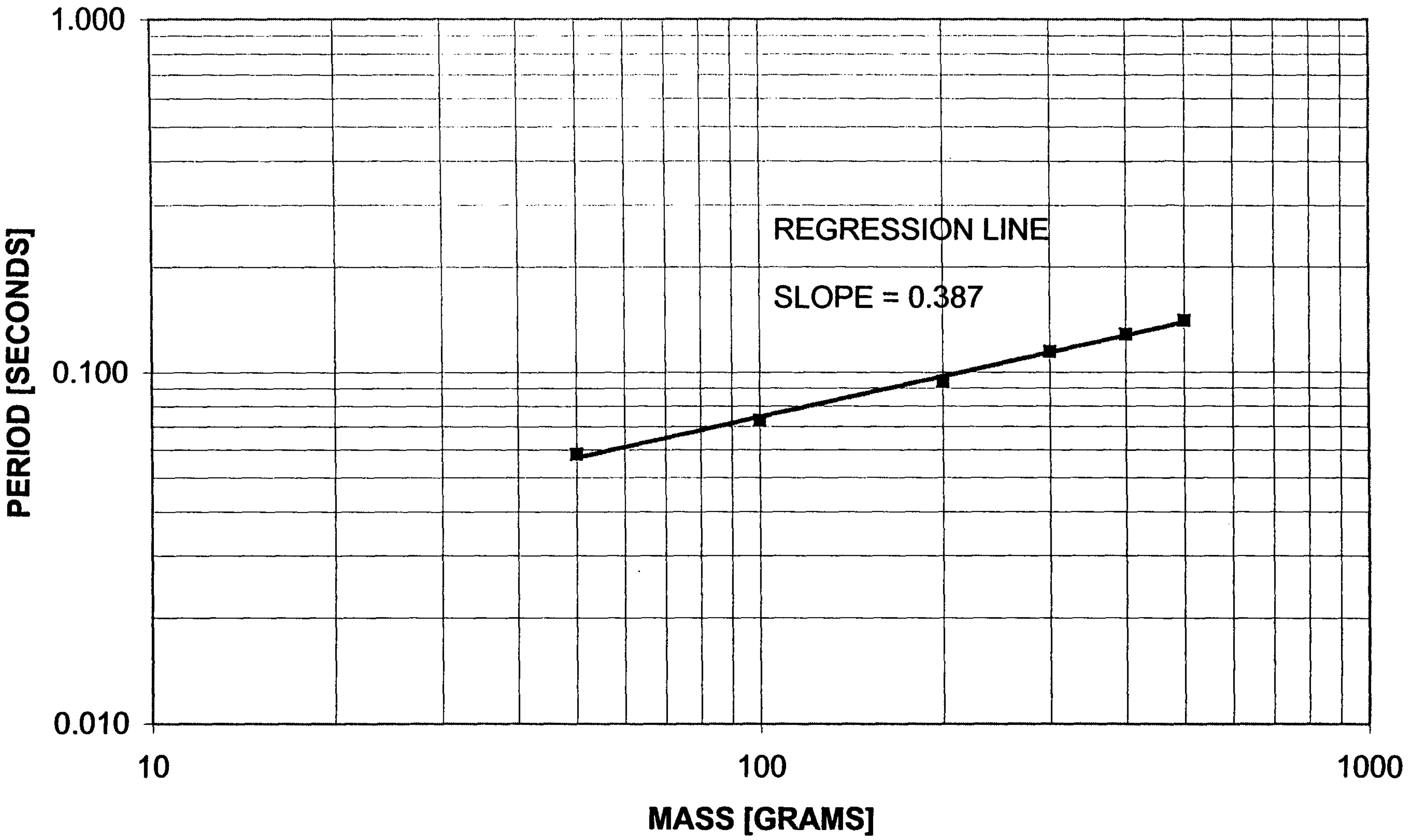
trial no.	mass (grams)	length (mm)	peaks	time (sec)	frequency (peaks/sec)	actual period (sec/peak)	theoretical period (sec/peak)
1	500	245	6	0.851	7.051	0.142	0.128
2	500	203.2	8	0.895	8.939	0.112	0.092
3	500	152.4	11	0.865	12.717	0.079	0.060

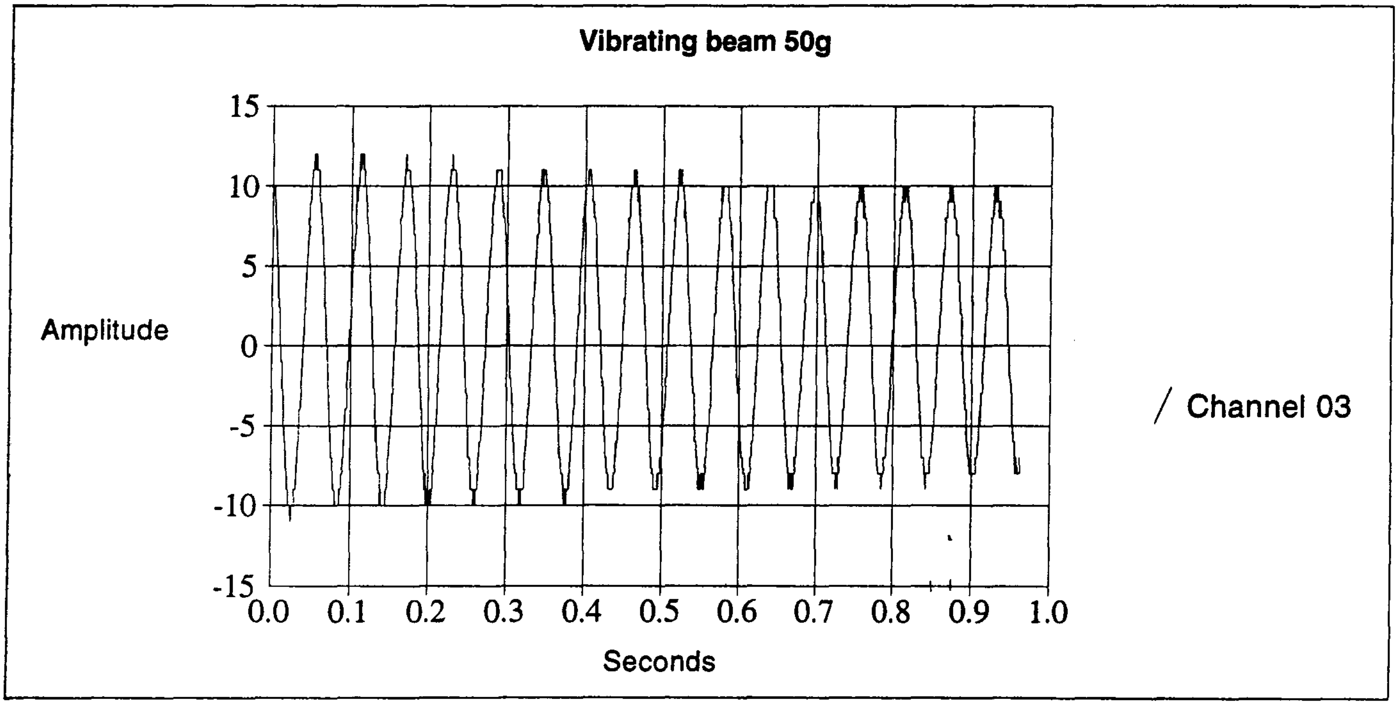
CHART 1							Slope	
			log M	log T	INTERCEPT	-1.902	Error	
MASS	period	Regression			SLOPE	0.387	-22.7	%
50	0.058	0.057	1.699	-1.234	R	0.9978		
100	0.073	0.074	2.000	-1.137	R^2	0.9956		
200	0.094	0.097	2.301	-1.027	SQRT(1-R^2)	6.6	%	
300	0.114	0.114	2.477	-0.942				
400	0.128	0.127	2.602	-0.892				
500	0.140	0.139	2.699	-0.853				
CHART 2							Slope	
length	period	Regression	LOG L	LOG T	INTERCEPT	-3.814	Error	
(mm)	(sec/peak)				SLOPE	1.241	148.2	%
245	0.141833	0.1416	2.389	-0.848	R	1.0000		
203.2	0.111875	0.1122	2.308	-0.951	R^2	0.9999		
152.4	0.078636	0.0785	2.183	-1.104	SQRT(1-R^2)	0.9	%	

PERIOD OF OSCILLATION OF A CANTILEVER BEAM



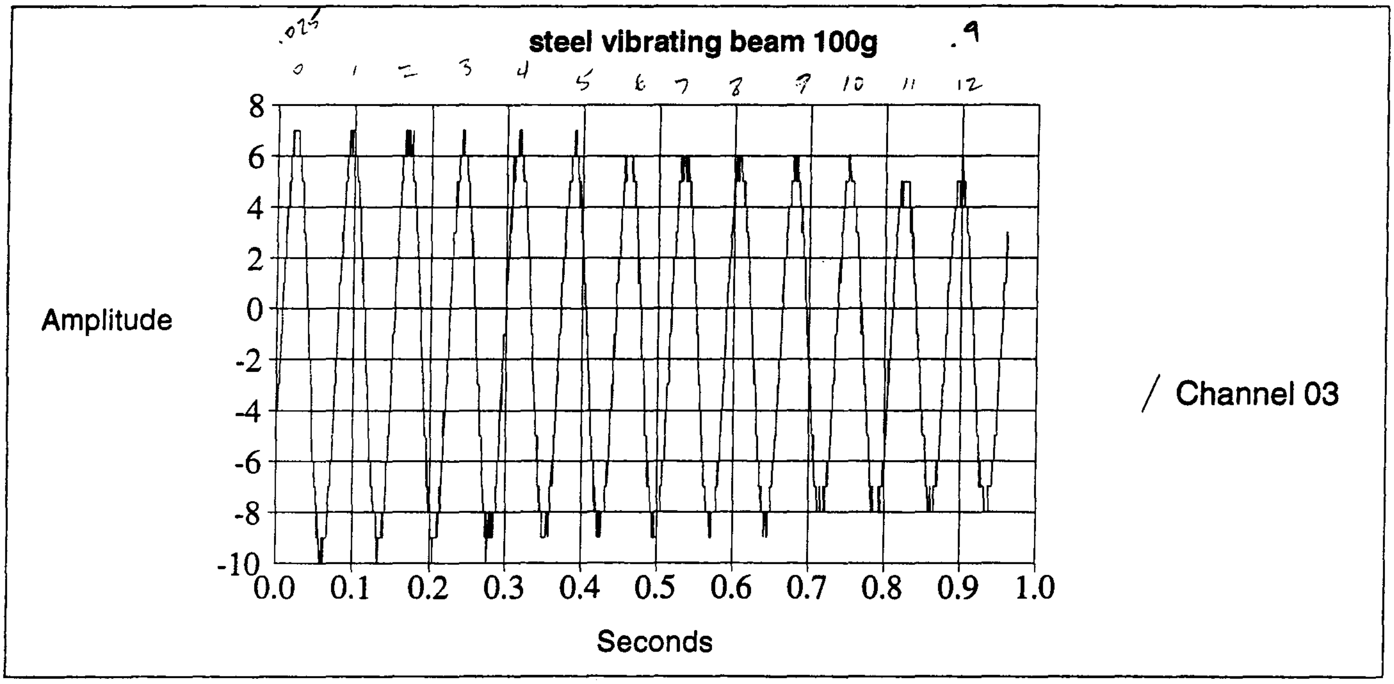
PERIOD OF OSCILLATION OF A CANTILEVER BEAM





$\Delta T =$

Peaks = 15

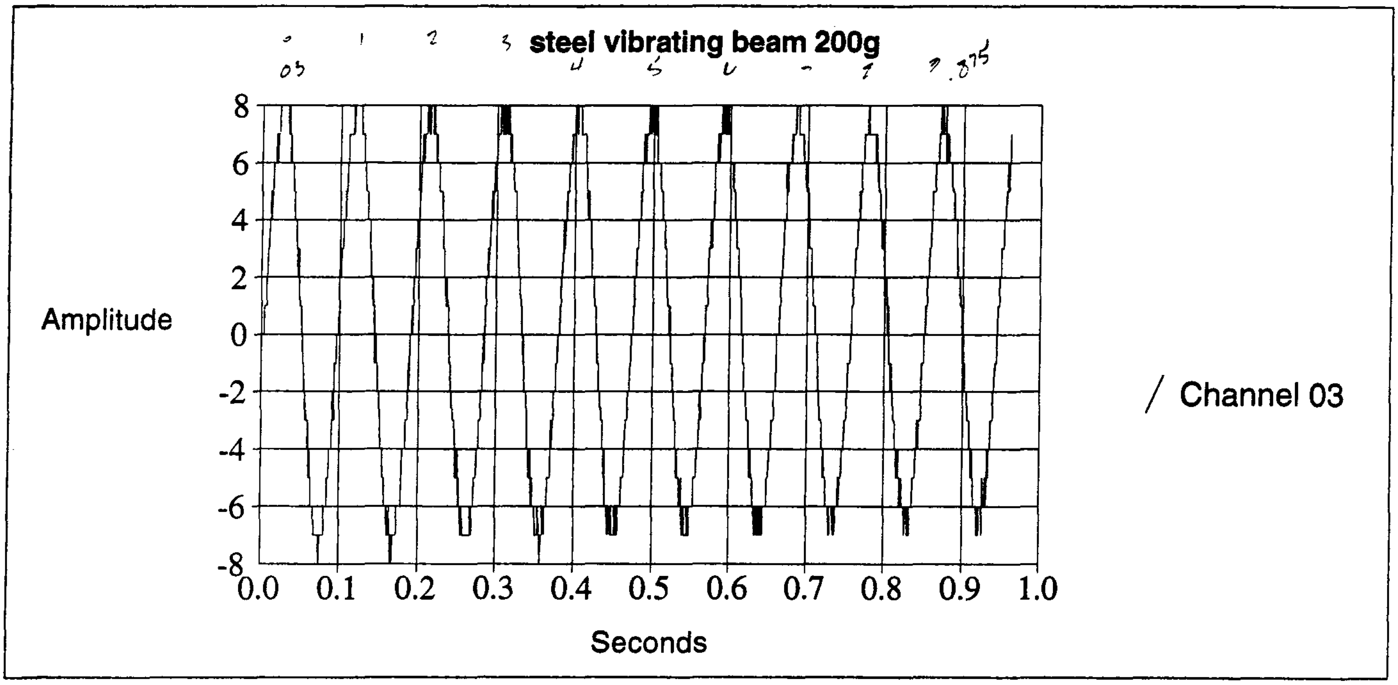


f = 13.714

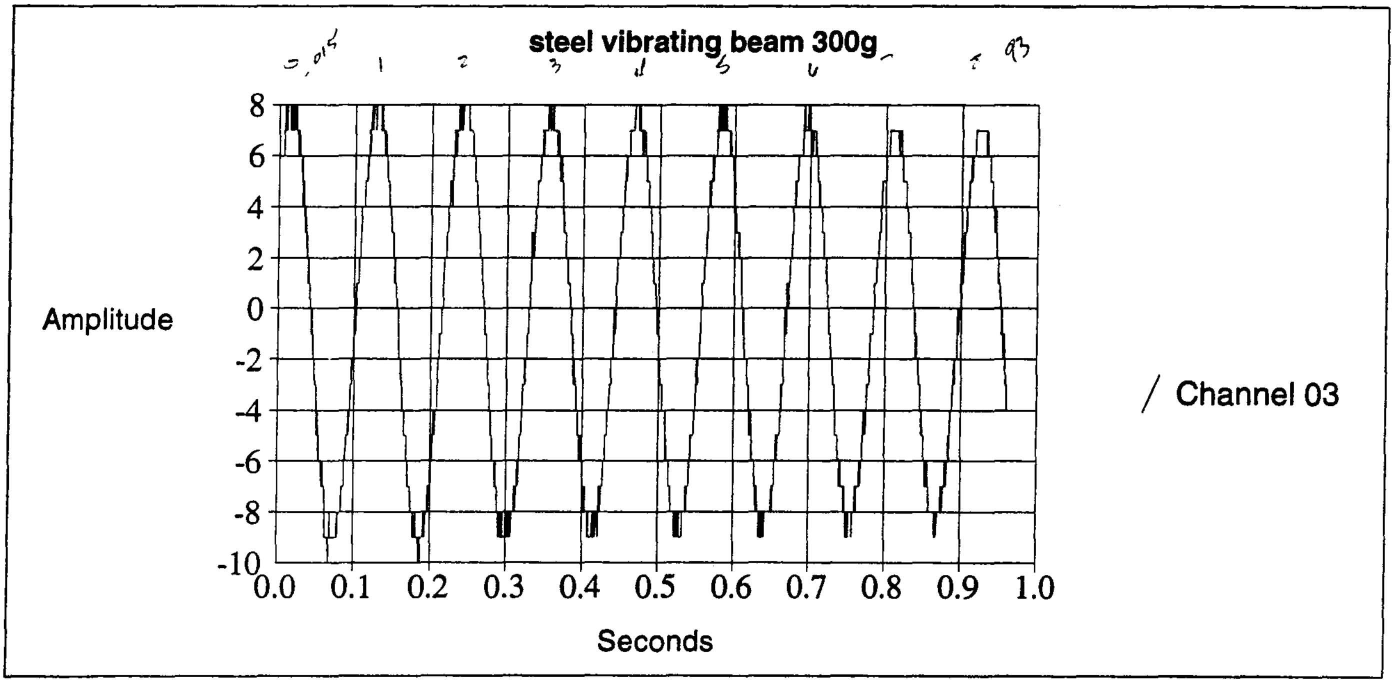
ΔT = .875

Peaks = 12

Period = .0729



f = 10.651
ΔT = .845
Peaks = 9
Period = .0939

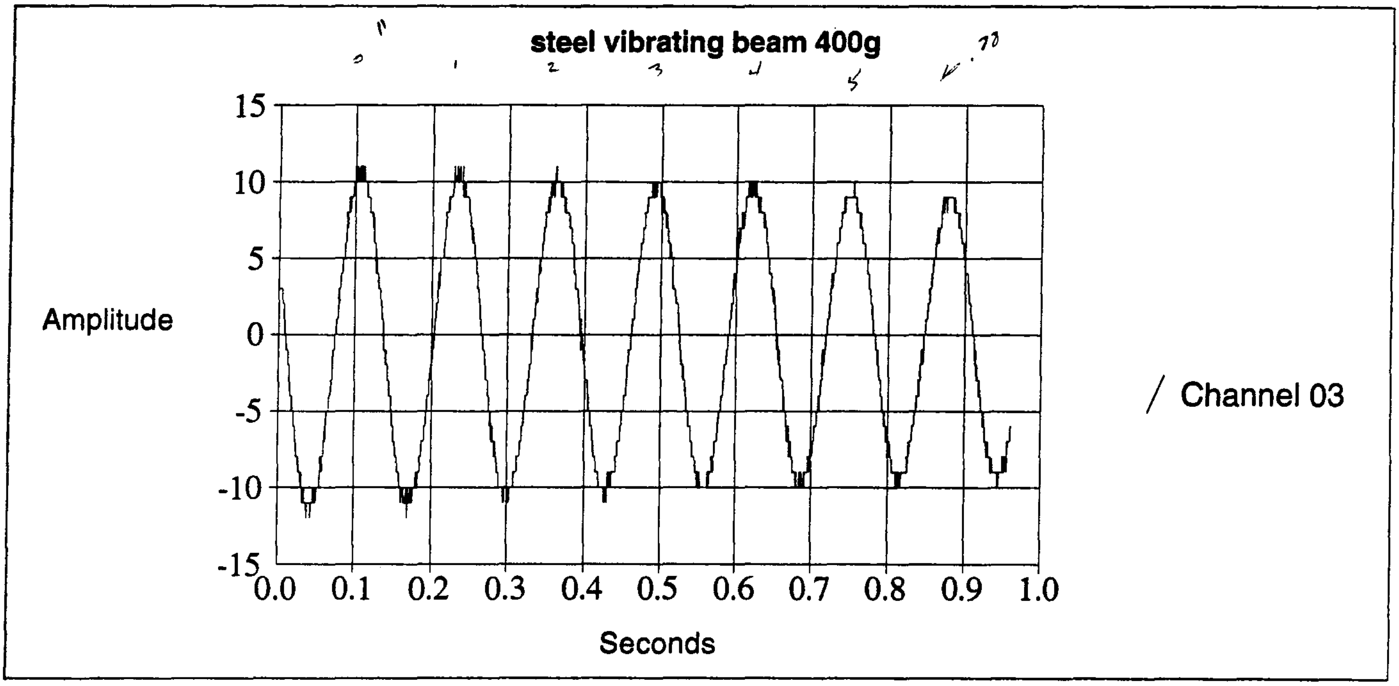


f= 8 743

ΔT= .915

Peaks= 8

Period= .1144

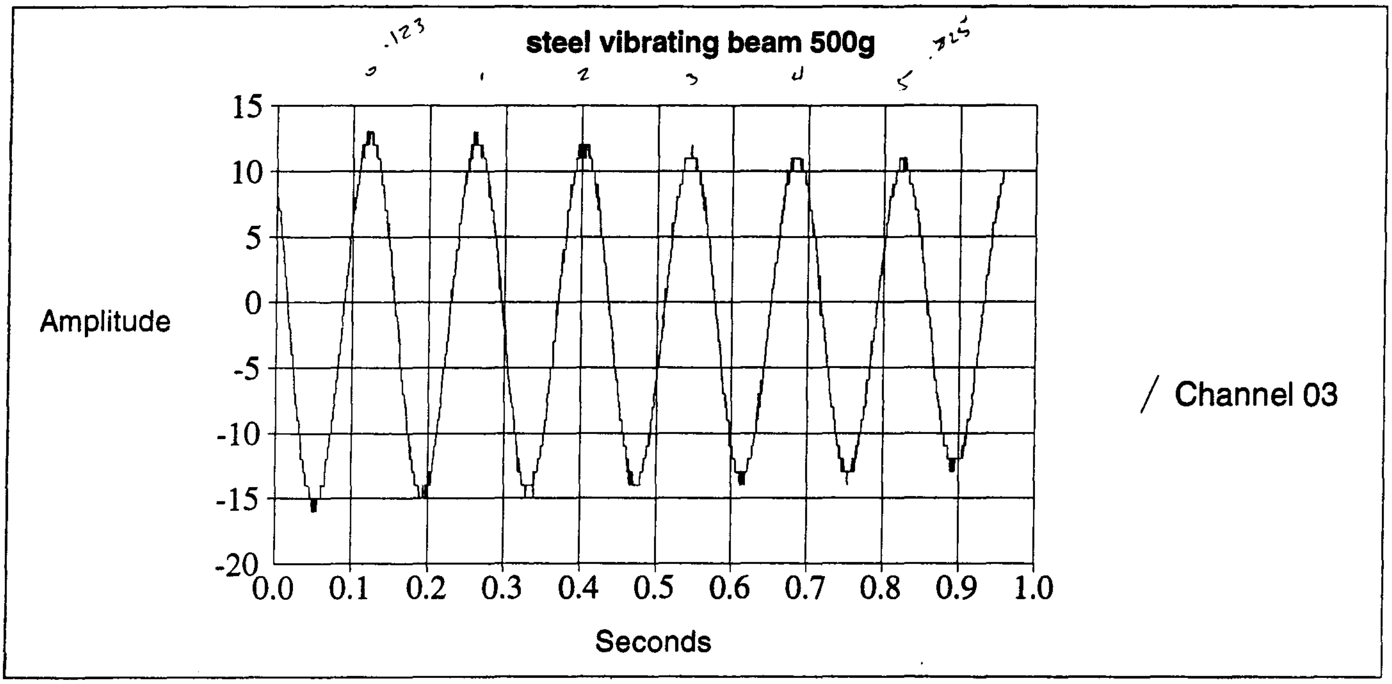


f = 7.792

ΔT = .77

Peaks = 6

Period = .1283



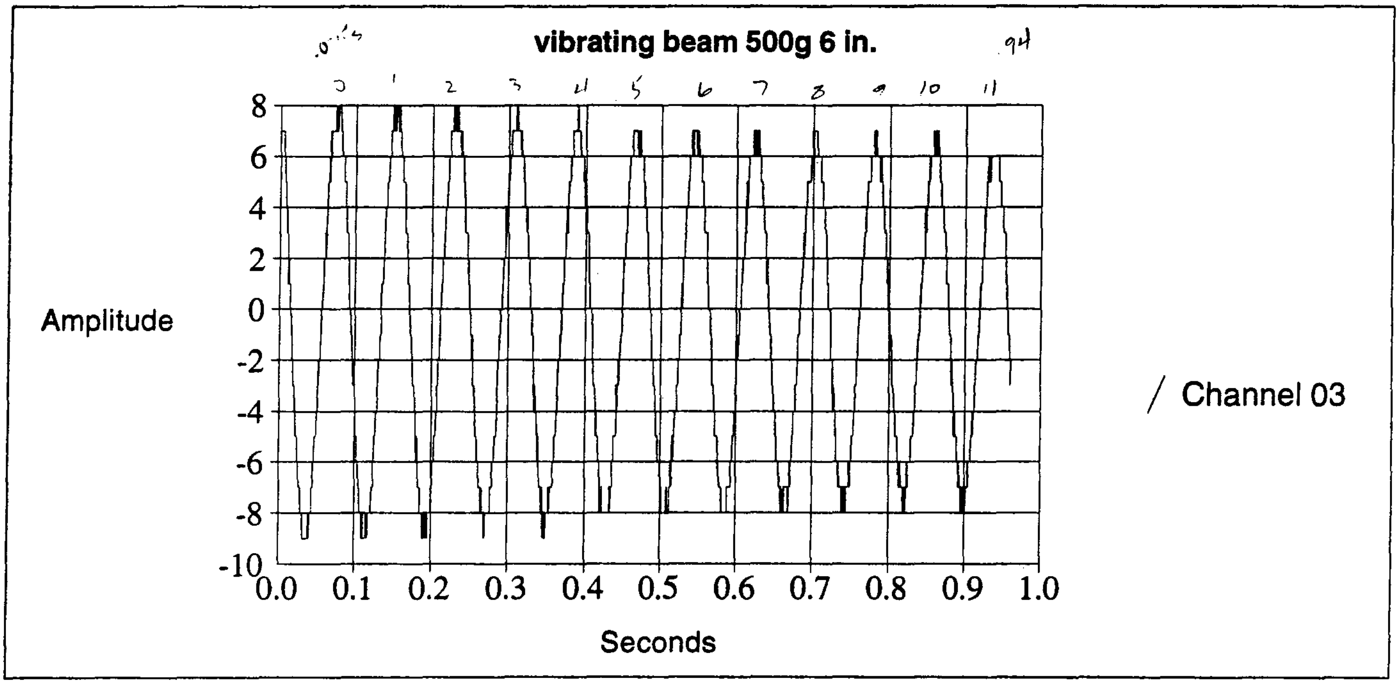
steel vibrating beam 500g

f = 7.123

ΔT = .702

Peaks = 5

∴ Period = .140

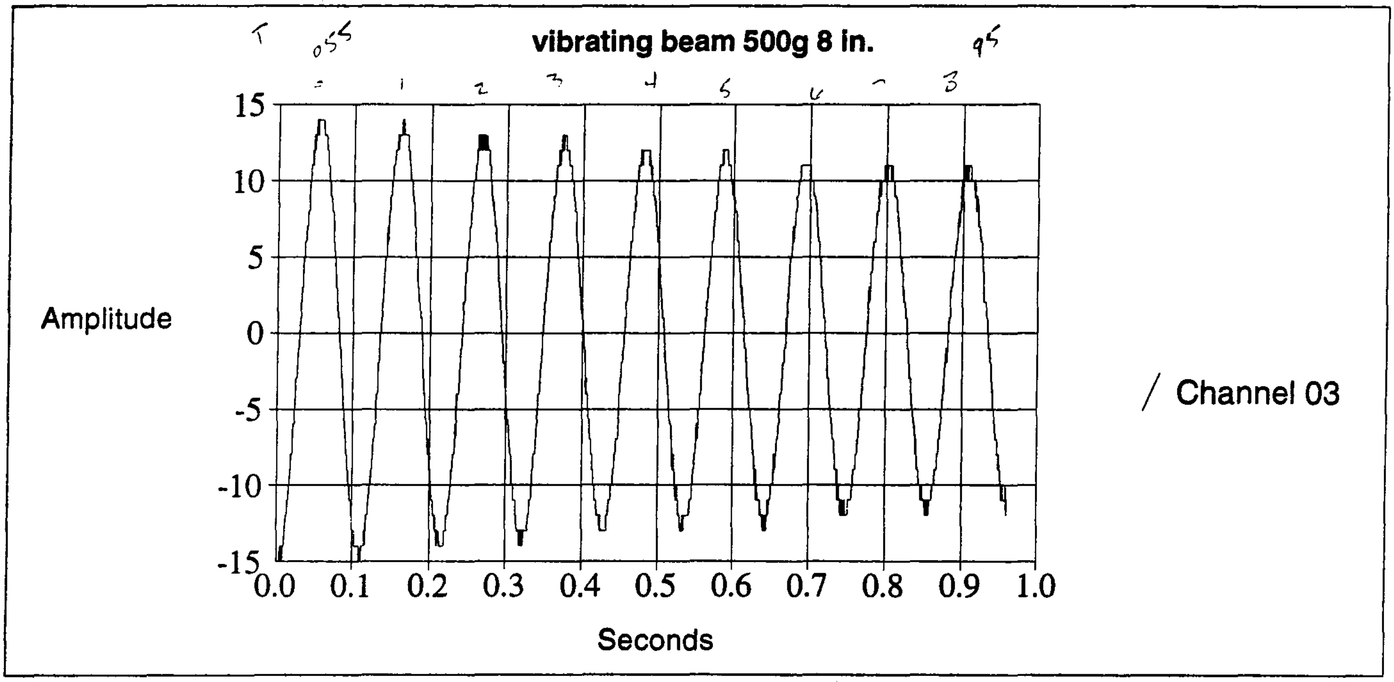


f = 12.717

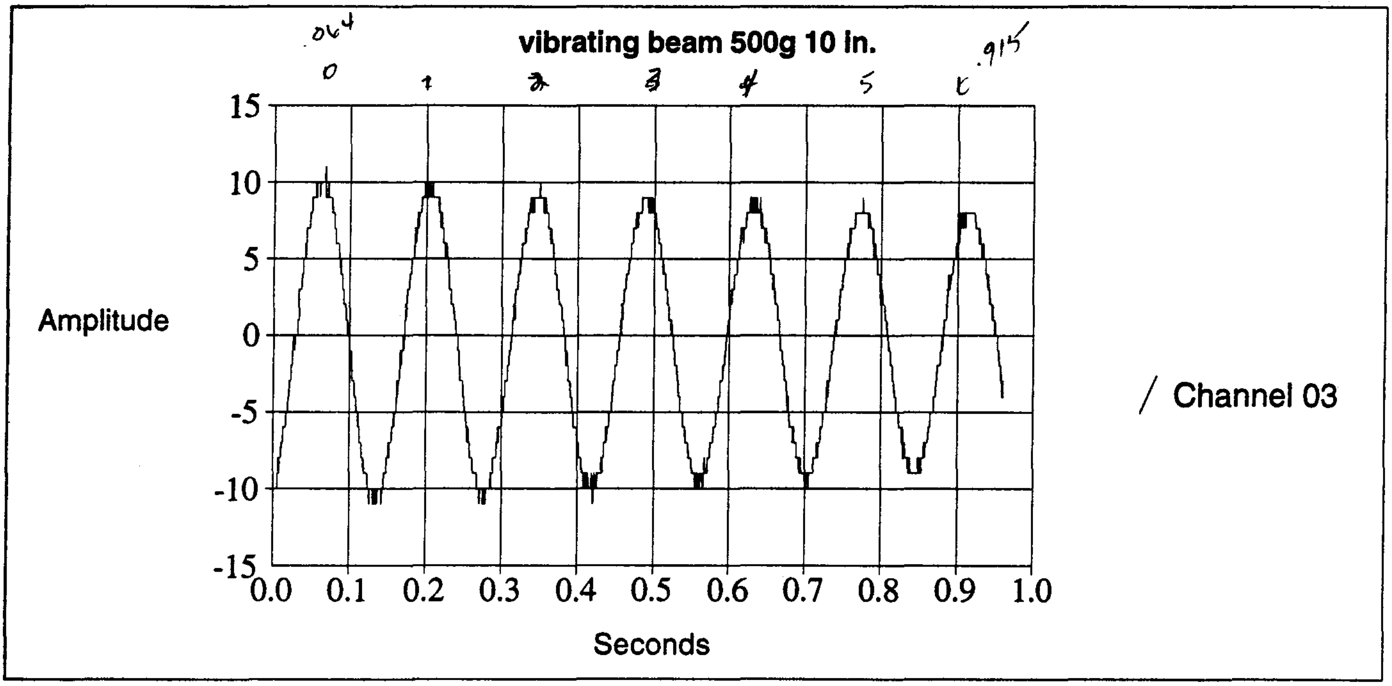
ΔT = .865

Peaks = 11

Period = .0786



f = 8.939
ΔT = .895
Peaks = 8
Period = .1119



f: 7.051

ΔT = .851

Peaks = 6

Period = .1418